PB81-153504

Recommended Specifications for Emission Inspection Analyzers

(U.S.) Environmental Protection Agency
Ann Arbor, MI

Sep 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-AA-IMS-80-5-B		PB81 153504

4. TITLE AND SUBTITLE	5. REPORT DATE
Recommended Specifications for Emission Inspection Analyzers	September 1980
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
William B. Clemmens	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
U.S. Environmental Protection Agency Office of Mobile Source Air Pollution Control Inspection and Maintenance Staff Ann Arbor, Michigan 48105	11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Same.	Technical
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Recently, there has been more emphasis on checking the performance of in-use vehicles. This is occurring through the implementation of state inspection and maintenance (I/M) programs as well as the forthcoming emission repair warranty regulations (207(b)) authorized by the Clean Air Act.

Practically all of the I/M data will be generated by field emission inspection analyzers (as opposed to laboratory equipment) in both centralized programs (i.e. central inspection lanes) and decentralized programs (i.e. inspection conducted by independent service centers). This data will affect the consumer through required maintenance, the automobile manufacturer through warranty claims, the State through emission credits, and the EPA through its ability to judge the effectiveness of the individual I/M programs. Obviously, a fundamental issue that an I/M program must deal with is the accuracy and validity of the test data taken under these programs. An inseparable part of that issue is the quality of the equipment used to obtain the data. Various state and trade associations have developed standards to control the quality of the equipment used, but as yet there are no nationally accepted minimum standards for inspection analyzers. An examination of the data validity issue should then encompass both -- Is the data generated under present conditions sufficiently valid?, and -- Is there a need for minimum quality standards for inspection analyzers? The subject of this report deals with these questions and issues.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Inspection Maintenance Motor vehicles Automobiles Exhaust gases Exhaust emissions Standards Analyzers Quality	Inspection/Maintenance Emission inspection analyzer	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited	Unclassified	118 p.
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

PB81-153504

EPA-AA-IMS-80-5-B

TECHNICAL REPORT

SEPTEMBER, 1980

RECOMMENDED SPECIFICATIONS

FOR

EMISSION INSPECTION ANALYZERS

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

EPA-AA-IMS-80-5-B

Technical Report
September, 1980

Recommended Specifications for Emission Inspection Analyzers

by

William B. Clemmens

NOTICE

Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analyses of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

Inspection and Maintenance Staff
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
U.S. Environmental Protection Agency

Note: This report (-80-5-B) is the second section of two sections. The first section -80-5-A contains Background, Technical Discussions, and Policy Information on Inspection Analyzers. Both sections (-A and -B) are available separately.

Table of Contents

	Page
Acknowledgments	5
—— Executive Summary ——	6
—— Technical Report —— Chapters I through V can be found in EPA-AA-IMS-80-5-A	
—— Analyzer Specifications ——	10
VI. How to Use The Specifications	11
A. Overview	11
B. Analyzer Technology	12
C. Change Notices	12
D. Definitions and Abbreviations	13
VII. Recommended State Minimum Specifications	16
A. Gases	19
B. Gas Cylinders	21
C. Durability Criteria	22
D. Design Requirements	23
E. Analyzer Performance	31
F. Sample System Performance	34
G. Operating Environment	36
H. Fail-Safe Features	37
I. System Correlation to Laboratory Analyzers	38
J. Manuals	39

Table of Contents (continued)

	Page
VIII. Additional System Specifications Recommended For Decentralized Inspection Programs	41
A. Automatic Zero/Span Check	41
B. Automatic Leak-Check	43
C. Automatic Hang-Up Check	44
D. Automatic Read System	45
E. Dual Tailpipes	45
F. Automatic Test Sequence	46
G. Printer	48
H. Vehicle Diagnosis	48
I. Anti-Tampering	48
J. System Diagnosis Testing	49
IX. Optional Features For The Inspection Analyzer	50
A. Automatic Data Collection	50
B. [Deleted]	52
C. Anti-Dilution	53
D. Loaded Mode Kit	54
E. Engine Tachometer	55
X. Future Improvements For The Inspection Analyzer	56
A. Introduction	56
B. Improvements in Water Removal	56
C. Improvements in HC Measurement	57
XI. Evaluation Procedures	59
A. Traceability of Analytical Gases	60
B. Gas Cylinder Specifications	61
C. Durability Test Procedures	62
1. Vibration and Shock	62
2. Sample Line Crush	64
3. Sample Handling Temperature Effect	67
4. Filter Check and Hang-up	
D. Design Requirement Inspection and Test Procedures	70
1. Useful Life	70
2. Name Plate	70
3. Sample System	70
4. Sample Pump	70
5. Sample Probe	70
6. Sample Line	70
7. Analyzer Spanning System	71
8. Analyzer Ranges	71
9. System Grounding	71
10. System Vents	71

Table of Contents (continued)

	Page
E. Analyzer Performance Test Procedures	72
1. Calibration Curve	72
2. Resolution	74
3. Compensation	75
a) Altitude	75
b) Pressure and Temperature	78
c) Non-Compensated Systems	81
4. Zero and Span Drift	82
5. Span Drift (see E.4.)	85
6. Noise (see E.8.)	85
7. Sample Cell Temperature	86
8. Gaseous Interference and Noise	88
9. Electrical Interference	91
10. Propane to Hexane Conversion Factor	95
F. Sample System Test Procedure	98
1. Sample Cell Pressure Variation, Low Flow and Response Time	98
2. (See F.1.)	102
3. (See F.1.)	102
4. (See F.1.)	102
5. System Leakage	103
6. (See C.4)	104
G. Operating Environment Test Procedure	105
H. Fail-Safe Systems	107
1. Warm-up Lock-out	107
2. Low Flow	109
I. System Correlation Test Procedures	110
1. NDIR Correlation	110
2. FID Correlation	114
J. Micro Processor Systems	117
1. Automatic Zero/Span	117
2. Automatic Leak Check	117
3. Automatic Hang-up	117
4. Automatic Read	117
5. Dual Tailpipes	118
6. Automatic Test Sequence	118
7. Printer	118
8. Vehicle Diagnosis	118
9. Anti-Tampering	118

Acknowledgments

The contributions and stimulating discussions with Merrill Korth and Gordon Kennedy of EPA during the formative stages of the technical specifications are greatly appreciated. The inputs and numerous reviews provided by the Equipment and Tool Institute Performance Test Group have greatly aided the preparation of this specification.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

EPA Recommended Instrument Specifications

The instrument used to measure motor vehicle exhaust concentrations of hydrocarbon (HC) and carbon monoxide (CO) is typically called a garage analyzer. This commonly used title has considerable significance to the I/M program Administrator choosing a minimum specification for exhaust analyzers. The word "garage" indicates the location where the instrument is used. "Garage" also refers to its intended use; to assist in the diagnosis and repair of engines and emission control systems. As those familiar with diagnoses and repair using an exhaust analyzer know, the relative level of pollutants, and the change in emission levels in response to an adjustment or repair, are most important in servicing a vehicle.

The I/M program places a new burden on these instruments: inspection. An inspection of the vehicle's exhaust requires an accurate measurement of the pollutant concentration, not just a relative level. Whether a vehicle requires repair depends on this measurement, and accuracy becomes an important consideration. The instrument must provide a repeatable measurement in order to assure equitable inspection for each motorist. The failure to achieve repeatability inevitably results in challenges to the program's credibility.

The current garage type repair analyzer has been used as an inspection analyzer in currently operating I/M programs. In centralized I/M programs, its design capability has been greatly complemented by computer control and very frequent calibration and maintenance. It is continually under the watchful eye of an experienced instrument technician, and its working environment is often carefully controlled.

In decentralized I/M programs, the repair analyzer has also been used as an inspection tool, but with little consideration for its original intended use. The one concession to this situation has been periodic state checks of the instrument's calibration.

In the garage environment, the inability of the repair analyzer to provide accurate and repeatable measurements is well established. A recent NHTSA study indicated 32 percent of field use exhaust analyzers were reading more than 15 percent too high or too low. The study had attempted to use the industry standard of accuracy of ±3%, but found virtually no analyzer could meet this requirement. At ±5%, 93 percent of analyzers were inaccurate or not repeatable.

In addition, the performance specifications of repair analyzers often are inappropriate for inspection purposes. As an example, most instruments are designed to operate at 0 to 85% relative humidity. As an inspection analyzer, this could preclude use on high humidity days. In many areas of the country, this specification effectively limits the use of the instrument for a large portion of the year. This is of course an impractical result, yet the instrument manufacturers have done nothing to rectify this problem.

Several attempts to improve the inspection analyzer by establishing minimum specifications have been made. In 1974, the California Bureau of Automotive Repair (BAR) published its first minimum instrument specification applicable to garages participating in its Blue Shield inspection program. In 1980 BAR upgraded this specification. This year, the Equipment and Tool Institute (ETI), an industry organization, published its own specification, and has widely disseminated it to states preparing I/M programs. EPA has reviewed each of these specifications and finds them lacking in two areas: 1) failure to consider how the operator affects the measured results, and 2) specificity of accreditation procedures.

Based on an error propagation model, EPA determined that the most important factor involving accurate exhaust measurements was proper operating procedures. EPA determined that incorrect gas spanning (calibration) could affect emission measurements by up to 40%, improper purging by up to 100%, leaks by 100%, and improper meter reading by 20%. Under the best of conditions, current equipment has a measurement accuracy of 25% to 35%.

The assessment indicated that minor, but important design changes could improve optimum accuracy to the 10 to 20 percent range. The improvements involve the detector, sample cell, and signal conditioning, and can be incorporated into existing designs with relative ease. EPA recommends that all states implementing centralized I/M programs adopt the EPA recommended specification for a manually operated analyzer. The specification, including detailed acceptance procedures, can be found in EPA-AA-IMS-80-5-B, "Recommended Specification for Emission Inspection Analyzers".

These improvements do not address the proper operation of the instrument. In centralized programs, this is dealt with through use of inspection personnel thoroughly familiar with the instrument, through recordkeeping and frequent calibration and maintenance, and often through real time computer control of the instrument.

In decentralized programs, the station operator or mechanic cannot be expected to become an instrument technician, the sophistication of the instrument precludes this. The cost pressures of completing the inspection as rapidly as possible encourage failure to provide proper calibration and leak checks. In fact, the calibration and maintenance requirements of these analyzers exceed those of any other garage instrument. Incompetence and fraudulent practices are also considerations in a decentralized program because of minimal inherent checks on the quality of the operation.

The advent of the $15 pocket calculator and the $800 home computer provides a practical solution to most of the problems of proper operation of the inspection analyzer in a decentralized I/M program. With the addition to each instrument of a small microcomputer, the inspection instrument can take on most of the calibration and recordkeeping burden. This computer operated analyzer will restrict operation until the unit is fully warm, will provide for automated gas span and leak checks, can accept vehicle ID and other information, will automatically make the pass/fail decision, will provide a hard copy output (which can include diagnostic information), and can store pertinent data on magnetic tape for future state analysis.

Such analyzers are not a wishful dream. One repair analyzer produced by Hamilton Test Systems incorporates some of these features and is commercially available. The New Jersey inspection program is currently evaluating a computerized unit produced by Sun Electric. New York State has recently contracted for over 4000 computerized analyzers for its decentralized I/M program. Given these recent developments, EPA's assessment of 9 to 18 months before quantities of units meeting its specification are available may be overly pessimistic.

EPA strongly recommends that each state implementing a decentralized I/M program adopt the EPA specification for a computer operated analyzer. The complete specification and detailed acceptance procedures can be found in EPA-AA-IMS-80-5-B ("Recommended Specifications for Emission Inspection Analyzers"). A drawing of an existing prototype follows this executive summary. EPA Report EPA-AA-IMS-80-5-A ("Analysis of the Emission Inspection Analyzer") provides considerable information on the need and benefits of adopting the computer operated analyzer.

Computerized features will increase the cost of the inspection analyzer. The attached report (EPA-AA-IMS-80-5-A) estimates that the full cost of the analyzer will be recovered for 2 to 3 dollars per test. In addition, the cost to the garage owner can be reduced through investment credits and depreciation. These considerations are fully discussed in the report. The estimated cost (1980 dollars) of the various types of analyzers is shown below.

EPA computerized	$6195 to 7395
EPA manual operation	$4490 to 5690
BAR 80 certified	$3750 to 4950
Current Repair Analyzer (ETI)	$3000 to 3750

The computer operator analyzer will allow a reduced frequency of state audits of licensed decentralized inspection stations. Because of the instrument's self-calibration feature, quarterly audits will provide quality assurance equivalent to the otherwise required monthly audits. This provision will reduce program administration costs, and should be an incentive for State adoption of the EPA recommended analyzer.

The impact on implementation schedules of the lead time to procure instruments meeting this specification is discussed in a separate memorandum to EPA's Regional Administrators from the Assistant Administrator for Air, Noise and Radiation.

Finally, the I/M staff at EPA's Ann Arbor facility is available to provide additional assistance and information as necessary. You may contact Tom Cackette, Donald White, or Bill Clemmens at (313)668-4367.

ANALYZER
SPECIFICATIONS

VI. How to Use the Specifications

A. Overview

The recommended specifications are presented in the next four chapters (VII through X). Chapter VII presents the basic specifications for inspection analyzers. Those specifications are designed to be consistent with manual operation of the analyzer. Chapter VIII describes the additional features that would be needed to create a computer operated analyzer from the basic Chapter VII analyzer. The performance aspects of the Chapter VII specifications are applicable to both the manual and computer operated analyzers.

Optional equipment such as automatic data aquisition for either type of inspection analyzer are detailed in Chapter IX. Chapter X provides some suggestions for future improvements that should be made to the basic analyzer.

An important aspect of any set of specifications is the interpretation of those specifications. The specific test procedures used to evaluate the performance of a piece of equipment essentially determines one interpretation of the requirements. Different test procedures can provide different results. The order that the tests are performed can also affect the results.

Chapter XI provides the EPA recommended evaluation test procedures. These procedures are intended to provide a consistent technique to verify analyzer performance. The suggested testing order is:

1. Follow manufacturer's initial start-up and pre-test procedure as listed in the manufacturer's manual(s).

2. Durability Tests

    1st - Vibration and Shock Test

    2nd - Sample Line Crush Test

    3rd - Temperature Effect

    4th - Filter Check

3. Inspection Design Requirements

4. Analyzer Performance

5. Sample System Performance

6. Operating Environment Test

7. Fail-Safe Features

8. Correlation Tests

If an analyzer passes the evaluation tests, the user can be fairly confident of the in-use emission test results from that particular analyzer. In order to apply the evaluation results to the general production line units, more analyzers must be tested. A recommended quality audit testing plan is provided in the introduction to Chapter VII.

B. Analyzer Technology

These specifications were determined based on current I/M practice of using non-dispersive infrared (NDIR) analyzers for HC and CO measurements. Nothing in these specifications should be construed as prohibiting other analysis techniques. Potential improvements in technology should be considered on a case by case basis. To that extent, many of the concepts expressed by these specifications can be applied.

C. Change Notices

At the present EPA has no formal mechanism for disseminating improvements or interpretations on subjects discussed in technical reports. The exception is if the report is published as part of a formal notice or regulation in the Federal Register. In that case, dissemination of changes occur through technical amendments, also published in the Federal Register.

In the case of this report, experience gained through widespread use will most likely lead to improvements in the test procedures. Further, new technology may obsolete certain parameters while at the same time require evaluation of new or additional parameters. The point to stress to State Program Managers is that any specification on I/M analyzers should allow some flexibility to deal with the issues just mentioned. However, the flexibility for change must be predicated on the concept of "meet or exceed" the criteria listed in the recommendations. In practically all cases verification of the meet or exceed criteria would be required, and would include comparison testing and statistical evaluation of the test data.

D. Definitions and Abbreviations

The following definitions are for reference. For many definitions, the specific test procedures used for verification of the specifications provide the final interpretation.

1. Accreditation: Certification that an analysis system has been tested by the required procedures, and it has been verified that the analysis system complies with those specifications. Further, accreditation implies that the analyzer manufacturer follows proper procedures to insure that subsequent production systems are also in compliance.

2. Accuracy: The combination of bias and precision errors, technically defined as Uncertainty, that quantify the difference between the analyzer reading and the true value (see equivalency).

3. Analytical Gases: Gases of known concentration used in the analytical process as a reference. The four basic categories are:

Gas	Use
a) Zero Gas	Laboratory, Manufacturer, and State Auditor
b) Calibration Gas	Laboratory and Manufacturer
c) Audit Gas	State Auditor
d) Span Gas	Field Emission Inspector

4. Analysis System: A system that incorporates an analyzer(s) and sampling components for the purpose of exhaust gas analysis.

5. Analyzer: A device that has the capability to identify unknown concentrations of particular constituents in automobile or truck exhaust gases by comparison to analytical gases. Commonly used interchangeably with "instrument".

6. Calibration: The act of defining or checking the full calibration curve of the analyzer. Generally considered a laboratory procedure, calibration requires 6 to 12 calibration gases per analyzer range or scale.

7. Calibration Curve: A curve (usually a polynomial) that describes the relationship between meter movement (i.e. chart deflection or voltage) and concentration level. For field instruments the calibration curve is usually fixed at the factory.

8. Calibration Gases: Analytical gases that are used to determine the accuracy of an analyzer calibration curve.

9. CO: carbon monoxide

10. CO_2: carbon dioxide

11. Detector: The portion of the analyzer that detects the constituent of interest, and provides the original signal proportional to the concentration of the constituent.

12. Drift: The average amount of change with time of analyzer reading. Two components of drift are:

a) Zero drift - average change in zero reading
b) Span drift - average change in the difference between zero and span readings

13. Dry-Basis Concentration: The resultant concentration after the water has been removed from the sample either physically or by electronic simulation techniques.

14. Equivalency: A statistical comparison of a candidate analysis system performance versus the reference analysis system performance on exhaust gas in order to determine the acceptability of the candidate system.

15. FID: Flame ionization detector. Most common laboratory analyzer used for determination of hydrocarbon (HC) concentrations in exhaust samples.

16. fs: Full scale of the analyzer.

17. Hang-up: Hang-up refers to the process of hydrocarbon molecules being absorbed, adsorbed, condensed, or by any other method removed from the sample flow prior to reaching the analyzer detector. It also refers to any subsequent desorbtion of the molecules into the sample flow when they are assumed to be absent.

18. HC: hydrocarbons

19. Instrument: see analyzer

20. Interference (electronic): Analyzer read-out errors caused by instrument response to electromagnetic sources and power supply variations. Common forms of electromagnetic sources are:

a) Radio Frequency Interference (RFI)

b) Very High Frequency Interference (VHF)

21. Interference (gases): Analyzer read-out errors caused by instrument response to non-interest gases typically occurring in vehicle exhaust.

22. L.S.: Low scale or range of the analyzer.

23. NDIR: Non-dispersive Infrared Analyzers

24. Optical Bench: The portion of the analyzer that consists of the main sample processing and detecting assembly. Generally included are the detector, optical filters, sample tubes, infra red source, and chopper systems.

25. Precision: Statistical quantification of random measurement errors.

26. ppm: parts per million by volume

27. ppm C: ppm by Carbon atom

28. ppm C3 or ppmp: ppm propane ($C_3 H_8$)

29. ppm C6 or ppmh: ppm n-hexane

30. Propane to Hexane Conversion Factor: A factor that accounts for the difference in analyzer response (relative response) between propane and n-hexane. Sometimes referred to as a "C" factor, or a propane equivalence factor (P.E.F.).

31. Response: Analyzer indication to a gas.

32. Response Time: The reaction time between a change in concentration at the inlet to the sample system and the time the analyzer indicates a given percentage of that change.

33. Sample System: The portion of the analysis system that is responsible for delivering an unaltered sample to the analyzer.

34. Span or Spanning: The act of adjusting the analyzer's calibration curve into the correct reference frame. Gas spanning uses a span gas for a reference during the adjustment process. Electrical spanning attempts to duplicate the span gas voltage level to be used as a surrogate reference during the adjustment process.

35. Span Gases: Analytical gases that are used to adjust or return the analyzer response characteristics to those determined by the calibration gases.

36. Zero Gas: An analytical gas that is used to set the analyzer response at zero.

VII. Recommended State Minimum Specifications

The recommended State minimum specifications are intended to be applied to both decentralized and centralized analysis systems. The particular specifications in this chapter are written with the assumption of manual operation of the analyzer. In order to perform the proper interactions, the operator must have a set of written instructions that are equivalent in function to the sequence of events performed by the computer analyzer specified for decentralized systems described in Chapter VIII. It is recommended that the analyzer manufacturer provide these written instructions, and it is necessary that the centralized programs implement these procedures in order to properly utilize the analysis systems.

These specifications are intended to apply to a manufacturer's entire production of inspection analyzers. In order to verify that the production line does meet the specifications, the testing plan in Table VII-1 is recommended. Reciprocity of qualification and QA/QC testing results should be accepted.

In preparing the analyzer for qualification or QA/QC testing, many evaluation test procedures require monitoring of internal analyzer signals or parameters. In order to decrease evaluation set-up time, the analyzer manufacturer may instrument the candidate analyzer(s) to provide convenient access to the necessary signals. No other modifications are allowed, and in some cases the manufacturer may be required to prove his instrumentation process does not affect the analyzer's performance.

Table VII-1

Recommended Qualification Program

I. Pre-Production

The manufacturer may receive a preliminary accreditation, valid for six months, by providing a publicly released report which demonstrates that at least one pre-production unit has passed all evaluation tests.

II. Initial Production QA/QC

1. The manufacturer shall also select, in a randon manner, three of the first 20 production units, and all three shall receive all evaluation tests.

2. If two of the three units pass all evaluation tests, the instrument shall receive full accreditation valid for a period of three years from the date the first unit was produced.

3. If two or more units fail the evaluation tests, corrections to the design and/or production must be made, and three additional units selected from a new or current production run. Two of these three must pass all evaluation tests.

4. All units covered by a preliminary accreditation and produced prior to the production run in which full accreditation is received shall be required to incorporate the necessary design and/or production fixes.

III. Subsequent Production QA/QC

The accreditation may be renewed for a three year period at any time by passing all evaluation tests on two of three units selected randomly from a production run of 20.

IV. QA/QC Testing Criteria

1. Two(2) of the three(3) production units must pass with no design or random failures.

2. A design failure is defined as a failure to meet the evaluation procedure criteria.

3. A random failure is defined as the failure of a standard part in the system (i.e. pump, electrical resistor, etc.) where improved procurement specification, assembly technique, or pre-assembly QC on that part would reduce failures in the field.

4. An infant mortality is defined as the total failure of a part (usually a computer chip or related components) within a short period of time after the unit first receives any electrical power. Infant mortality failures must have sufficient documentation (i.e. published report available to regulatory bodies) to justify why the failure can be attributed as infant mortality and

not minor design failure. Infant mortality failure is not classified as an analyzer failure if the failure would be obvious in the field. After repairs, those tests that might be affected by the repairs must be rerun.

5. Random failures must have sufficient documentation (i.e. published report available to regulatory bodies) to justify why the failure can be attributed as a random failure and not minor design failure. Random failures may be repaired on pre-production units only. A condition to allow the repair of the pre-production analyzer is the development of a plan (where necessary) to prevent the specific type of failure in production units. After repairs, those tests that might be affected by the repairs should be rerun.

A. Gases

1. Accuracy

a) Calibration and Audit gases: ± 2% of True Value, or
± 1% of NBS Standard Reference Material (SRM)

b) Span gases: ± 3% of True Value, or
± 2% of NBS Standard Reference Material

c) Zero gases: less than 10 ppm C hydrocarbon
less than 50 ppm CO
less than 1000 ppm CO_2

2. Composition

a) Span gases should be CO and HC (propane) with N_2 as diluent

b) Calibration and Audit gases should be:

i) HC (propane) with N_2 as diluent, and

ii) CO with N_2 as diluent

c) CO_2 with N_2 or air zero gas as diluent (span or calibration)

d) Zero gas may be

i) bottled air,

ii) chemically purified room air such as with an activated charcoal trap on the analysis system, or

iii) catalytically purified room air

e) Hexane to propane conversion factor checking gases shall consist of n-hexane in nitrogen, gravimetrically blended to the accuracy of SRM's. The gravimetric analysis is only valid for 1 year from the date of analysis unless historical data and correlation checks can verify stability of the gas concentration. The gravimetric analysis is void if the gas cylinder temperature drops below 20°C (68°F) for any reason including shipping and storage. An alternative to the 20°C minimum temperature is to condition the gas cylinders at least one week after receipt of the cylinders in a temperature environment between 27°C (80.6°F) and 48°C (118°F). During the one week conditioning, the cylinders shall be stored on their sides, and rolled at least once a day. Storage thereafter should be above 20°C (68°F). The required concentrations are:

i) 250 ppmh (± 15 ppmh)

ii) 1500 ppmh (± 150 ppmh)

3. Recommended number of gases

a) for evaluation testing

i) 7 equally spaced concentration values of calibration gases per range

ii) bottled zero gas

iii) 2 concentrations of hexane/propane conversion factor checking gas

iv) 1 cylinder of 14% CO_2

v) 1 cylinder of 100 ppm NO_2

b) for in-use systems

i) one span gas concentration between 70-95% of fs on low range for each HC and CO analyzer. For standardization, 1.5% CO and 600 ppm C_3 are prefered.

ii) purified room air zero gas

iii) for systems that use a CO_2 analyzer, on span gas concentration between 8 to 12 percent CO_2. For standardization 10% CO_2 is prefered.

c) for periodic check (i.e. State audit) of in-use systems (final guidelines will appear in follow-on EPA recommendations for State audit quality assurance programs)

i) a minimum of 3 concentrations per range for each analyzer, or

ii) one concentration for each cutpoint and 207(b) standard (if applicable) with a concentration value within 10 percent of the cutpoint (need not exceed 5 concentration levels), and

iii) bottled zero gas

iv) one cylinder of 14% CO_2

B. Gas Cylinders

1. In-use Span gases

a) Gas cylinder should be of a "1A" or "T" size. Single blend capacity (HC in air or CO in N_2) is generally around 200 cubic feet at 2000 psi. Dual blend (HC and CO in N_2) is generally around 160 cubic feet at 1600 psi.

b) All cylinders shall meet DOT specifications for "1A" or "T" cylinders.

c) Gas cylinders smaller (or larger) than the "1A" or "T" size may be used provided that:

i) The analysis system gas useage for the various operations (i.e., gas span, leak check, etc.) is such that the span gas in the smaller (or larger) cylinder will last at least 6 months when using the recommended frequencies of those operations. Span gas useage rate should be identified during the evaluation testing.

ii) The analyzer manufacturer performs a source study to insure adequate availability of the smaller (or larger) cylinders in sufficient quantity to service analyzers using that bottle size.

iii) Regardless of the results of the source study, if the smaller (or larger) cylinders are not available in some areas, or if those cylinders become unavailable at a later date, the manufacturer must make available a retrofit kit that will allow the use of a "1A" or "T" cylinder.

d) Disposable cylinders may not be used.

2. Concentration Label

A semi-permanent label shall be affixed or attached by the Certifying Laboratory to each gas cylinder with the following information.

a) Name of the Gas Blender

b) Name of the Laboratory Analyzing the Gas Blend

c) Cylinder I.D. number

d) Date of Analysis

e) Traceability to NBS or to other certified EPA Mobile Source Standard

f) Statement of Impurities (See accuracy and composition requirements)

g) Gas Concentration

C. Durability Criteria

1. Vibration and Shock Test (See Test Procedure) :
   a) span shift: 2% fs LS
   b) All analyzer and system performance checks must be met.

2. Sample Line (see Test Procedure)

   a) Line crush :
      i) No visible failure or deterioration
      ii) Meet leak check specifications
      iii) Meet response time specifications

3. Sample Handling System Temperature Effect :
   a) Unloaded System - 20 minutes 600°F sample inlet
   b) Load System - continuous at 1000°F sample inlet
      a) No visible failure or deterioration.
      b) Meet leak check specification.
      c) Meet response time specification.
      d) Meet HC hang-up specification.

4. Filter Check (see Test Procedure)

   a) 2 hr sample time :
      i) Low Flow Not Activated
      ii) Meet Leak Check specifications
      iii) Meet Response Time Check
      iv) Meet HC hang-up check

   b) Sample until "low flow" indication :
      i) Time until "low flow" system activates or 20 hr of sample.
      ii) Until the low flow system activates the system response time must be met.

D. Design Requirements

1. The analysis system shall be designed with a design goal of a 5 year minimum useful life. Useful life has terminated when the analysis system can no longer be repaired to meet the specifications in this document at a cost of less than 60 percent of the replacement cost at the time of repair.

2. NAME PLATE Permanently Located and Readable.

a) Analyzer System Manufacturer

i) Name
ii) Address
iii) Phone number (customer service)

b) Analyzer Model Number and Serial Number

c) Date of Analyzer System Assembly

3. Sample System

a) Sample system components should be designed for intermittent sampling (20 minutes out of 10 hr.) of 600°F inlet (to probe) exhaust temperature. Such systems shall be designated "Unloaded" analysis systems. Systems designed for continuous duty with a minimum of 1000°F inlet (to probe) exhaust temperature, and proper sample handling equipment (i.e. water removal and/or heated lines) may be called "Loaded" analysis systems.

b) The type of system (Loaded or Unloaded) shall be permanently attached and prominently displayed in large letters.

c) The materials used in the sample handing system shall not alter the exhaust sample. Some examples of non-reactive materials are teflon®, viton®, stainless steel, silicone rubber (red), and in some areas nylon®. Some examples of reactive materials are, brass, copper, and tygon®.

d) Water Trap:

i) A water trap shall be included in the sample system. The trap shall be self draining, visible to the operator, and the sample system shall be designed to prevent condensable water from occurring in the sample system downstream of the water trap. The following options may be used but are not required.

1. Option 1: A dry-basis measurement is permitted if the absolute moisture content entering the analyzer is less than the saturation moisture content at a sample gas temperature of 7°C (45°F). Ice traps or refrigerators are permitted.

2. Option 2: Electronic correction to a "dry-basis" reading is permitted if the temperature and pressure of the sample after the water trap is measured and the sample is assumed to be saturated at the measured temperature. The water correction system must be de-activated for leak checks.

e) Particulate Filter

i) A particulate filter(s) shall be included in the sample system.

ii) The major or pre-filter (if used) shall be located in a manner that allows convenient filter element replacement.

iii) The proper direction of flow for the filter body(s) and element(s) (if applicable) shall be indicated in a manner that is easily discernible.

iv) The filter body shall be designed to provide leak free operation with normal filter element changing frequency for the lifetime of the analyzer, or a parts list of specific replaceable parts shall be listed in the maintenance manual as parts that may contribute to sample system leaks.

v) If a filter(s) is on the vacuum side of the system, all manuals and filter element replacement instructions shall indicate that the system should be leak checked every time a filter element is changed. A similar message should be located on or near the filter body(s).

vi) The filter element and filter system shall be designed to prevent particulates larger in size than 5 microns from entering the sample cell of the analyzer. The location of this optical bench 5 micron filter is up to the manufacturer and may be on the pressure or vacuum side of the system. If this filter only filters sample gases passing through the analyzer, the manufacturer may elect to have an additional filter prior to the system pump(s). The particulate size of this optional filter is at the discretion of the manufacturer. Verification of filter particulate size removal is permitted to be determined by the filter manufacturer using standardized ASTM or Filter Industry procedures.

4. Sample Pump

The sample pump shall be designed for at least a 2000 hour life of continuous duty.

5. Sample Probe

a) The probe must sample at least 16 inches from the end of the tailpipe or dilution adapter.

b) The probe shall have a flexible portion that will allow the probe to be inserted in a 1½ inch O.D. tailpipe. Assume the tailpipe has a 3 inch radius 90° bend beginning 4 inches from the end of the tailpipe.

c) The probe shall be designed for easy servicing and/ or replacement.

d) A leak proof dilution adapter (tailpipe extender) shall be provided. Multiple adapters may be used.

e) The tailpipe extender shall be able to be attached to the vehicle within 60 seconds.

f) The tailpipe extender shall be designed to allow the attachment of standard service center building exhaust evacuation systems without affecting the vehicle or measurement process. The pressure at the end of the tailpipe or extender should be within ±2 inches of water of the ambient barometric pressure.

g) The tailpipe extender shall not alter the sample and the material shall conform to D.3.c.) of this chapter.

h) The probe and tailpipe extender shall have sufficient hardware (insulated handles, etc.) that will allow the user to insert, attach, or remove the probe or the dilution adapter safely and conveniently.

i) The probe or tailpipe extender shall be designed in a manner that will prevent the probe or extender from being removed from the vehicle unintentionally.

j) All probes should have a smooth surface near the probe tip before the flexible portion of the probe to be used for sealing of the span gas adaptor necessary for field or on-board leak checking (gas comparison) or response time checking equipment. For standardization the sealing surface should be ½ inch in outside diameter and ½ to 1 inch long.

6. Sample Line

a) The sample line shall be sufficiently flexible at the temperatures to be encountered during vehicle testing (See Section G)) to allow normal inspection operations. Pliability need only be demonstrated at the lower operating environmental temperature.

b) The sample line shall not be longer than 25 feet nor shorter than 15 feet (excluding the probe). For standardization 20 feet is preferred.

c) The portion of the sample line in contact with the exhaust gases shall not alter the exhaust sample, and shall minimize HC hangup, due to absorption, adsorption, desorption, outgassing, etc.

d) The manufacturer must state the estimated useful life of the sample line in the instruction manual.

7. Analyzer Spanning System

a) Minimum Gas Spanning Frequency: The analyzer shall be designed for routine gas spanning every 180 hours (once per week).

b) Recommended Gas Spanning Frequency: It is recommended that the analyzer be gas spanned after:

i) every "power on" and warm-up sequence, and

ii) every 4 hours of "power on" condition when testing.

c) Minimum Electrical Spanning Frequency: All analyzers shall be electrically spanned every hour when testing.

d) Optional Spanning Frequencies: Three equipment options may be substituted for the 4 hour recommended gas spanning frequency. (These options may reduce the use of span gas). Details of these options are found in subparagraphs m), n), and o) of this section.

e) The analyzer shall be routinely spanned with flowing zero (purified room air) and span gases. A convenient port for periodic (i.e. audit) spanning with bottled zero gas shall be provided. A separate audit port for audit gas shall be provided to alleviate the necessity to disconnect the span gas in order to perform the audit test. The audit port should interconnect the span system downstream of the span/zero switching valve.

f) The gas spanning operation must allow the operator to easily correct for changes between the gas span point gain and the electrical span point gain. In all cases the electric span point gain is the parameter that must be changed such that the new electric span point gain setting will cause the analyzer to read the span gas properly. For manual operation, the manufacturer shall provide a step by step sequence in the operators manual equivalent to the automatic system recommended for decentralized units.

g) If the analyzer is equipped with multiple ranges, there shall be convenient access for audit or service personnel to adjust or trim the scale factor between ranges. When trimming the scale factor, start on the highest range and work down. When spanning the analyzer, start on the lowest scale and work up.

h) When the analyzer is initially installed at a new sight, the analyzer span gain for a proper gas span shall be logged in the analyzer's log book. A numbered span adjustment knob may be used for this purpose, or the physical gain adjustment of the front panel controls may be limited to the values listed. The limited gain control option shall include visable reference to the range

of initial adjustment and to the range approaching mandatory maintenance. Generally this mandatory maintenance would include cleaning of the sample cell. Criteria: If the adjusted span gain for any subsequent spanning operation exceeds 140% of the initial value logged in the book, the operation manual shall indicate that the system is approaching a mandatory maintenance criteria. The operation manual should indicate operation of the analyzer with gain settings exceeding 150% of the logged initial value constitute improper operation and the analyzer needs repair. The user (State, contractor, owner/inspector, etc.) is responsible for proper operation of the equipment.

i) The span point for all analyzers shall be between 70 and 100 percent of full scale on the lowest range. For standardization the preferred values are 1.5% CO and 600 ppm C3.

j) Appropriate valves, switches, and electrical controls shall be provided that will allow the operator to conveniently select zero, span, or sample gases, and zero and span the analyzer.

k) Determination of Test Value.

i) The analyzer shall have a selector switch or button (with indicator) labeled "Sample" or "Test".

ii) Activation of the "sample" switch shall cause the analyzer system to begin integrating or averaging the analyzer response 17 seconds after the switch is activated, and continue integrating the analyzer response to a flowing sample for the next 15 seconds. The sample and hold circuits can be either analog or digital. Digital sample rates shall be at least 10 hertz. An optional start integration time is described in Chapter VIII paragraph D.2. The option may be used if the criteria are met.

iii) The analyzer read-out device shall display the integrated value, and hold the display until reset. An indicator light shall signal the operator when the integrated value is displayed.

l) Span cylinders

i) For stand alone centralized inspection analyzers (a condition determined by the State or Contractor) and all decentralized analyzers, the analysis system shall include a structure for safely securing two "1A" or "T" size cylinders (i.e. 160-200 cubic foot bottles) unless the manufacturer has elected to use a different cylinder size as outlined in Section B. on gas cylinder specifications. Appropriate regulator(s) and lines shall be provided for one dual blend (HC and CO in N_2) cylinder. If the system includes a CO_2 analyzer, regulator(s) and lines shall be provided for one cylinder of CO_2 span gas.

ii) For centralized systems utilizing multiple analyzers in a single location, the analyzer manufacturer need only supply span gas and bottled zero gas ports on the analyzer. The user (i.e. State or Contractor) is responsible for the span gas manifold system including lines and regulators.

iii) Optional Span Cylinder Location: An analyzer manufacturer may elect to not locate the span bottles on the analyzer structure by providing a bottle cart or rack to secure the span bottle(s). The bottle cart must safely secure two "1A" or "T" size cylinders (unless other bottle sizes are used). Non-reactive quick disconnect connections must be used on the span gas lines between the cart system and the analyzer.

m) Optional Spanning System 1a: The analysis system may provide temperature and pressure compensation to the analyzer output and spanning system. The compensation shall be based on sample cell gas pressure and sample cell inlet gas temperature. If such a system is used, and verified by subsequent checkout, an electrical span check may be substituted for the "power on" and 4 hour gas span checks, but not for the weekly gas span checks. During analyzer checkout, only one gas span check is allowed as part of the initial analyzer set-up prior to the initiation of the entire check out procedure. An electric span shall be substituted for all gas spanning operations in Chapter XI (unless otherwise noted). Additional tests will be required in order to verify the accuracy and linearity of the compensation network at the various atmospheric pressures and temperatures required by the performance specifications (Chapter VII, Secion E).

n) Optional Spanning System 1b: A pressure and temperature monitor system would be considered to be in compliance with the provision of optional spanning system 1a, if the system monitors the sample cell gas pressure and inlet gas temperature continuously. If these parameters exceed 4 inches H_2O and/or 10°F difference from the most recent gas span, the analyzer would subsequently and boldly alert the operator of the need for a new gas span check (for manual systems). For decentralized systems, the compensation system shall perform as above as well as prevent further operation of the analyzer (unless the computer automatically gas spans the analyzer without any operator input).

o) Optional Spanning System 2: The basic accuracy and precision of the analysis system may be significantly better than the specifications put forth in this document. In such a case, the analysis system may be capable of meeting the specifications of this document without any pressure and/or temperature compensation of the analyzer output and spanning system. If such a claim is made, and verified by subsequent checkout, an electrical span check may be substituted for the "power on" and 4 hour gas span checks, but not for the weekly gas span checks. During analyzer check out,

only one gas span check is allowed as part of the initial analzer set-up prior to the initiation of the entire checkout procedure. An electric span shall be substituted for all gas spanning operations in Chapter XI (unless otherwise noted). Additional tests will be required in order to verify the accuracy of the analysis system at the various atmospheric pressures and temperatures required by the performance specifications (Chapter VII, Section E).

8. Analyzer Ranges

a) Low-Range :
i) 0-400 ppmh HC
ii) 0-2% CO

b) High Range :
i) 0-2000 ppmh HC
ii) 0-10% CO

c) An analyzer may use one range for HC or CO corresponding to the high range values provided that the low range portion (0-400, 0-2%) meets all of the analyzer specifications as if that portion were a separate range. During check out of the system the 0-400 ppmh and 0-2% portions of the high scale shall be treated as a low range scale.

d) All analyzer read out devices (digital or analog) shall be appropriately scaled and capable of reading negative values up to -5 percent of full scale for each range regardless of operational mode (sample, span, leak check, etc.). The sample operational mode may prevent negative readings if a diagnostic switch allows such readings (negative ones) to occur for diagnosis of analyzer problems.

e) All manufacturer's literature shall provide an explanation on the difference between ppm propane and ppm hexane. All formal or technical reports should clearly identify measured HC results as ppm hexane.

f) All multi-range analyzers shall have range indicating lights that clearly indicate which meter scale is to be read. The lights shall be of sufficient intensity and color that will allow an operator to identify the range selection in sunlight from a distance of 15 feet.

g) Additional analyzer ranges may be used provided that they meet all specifications pertaining to the recommended ranges.

9. System Grounding

a) All systems shall have a 3 wire power cord with a 3 prong grounded plug.

b) The manufacturer's representative should check upon initial installation to insure that the system is properly grounded to prevent ground loops from interfering with the analyzer.

10. System Vents

a) No restrictions such as flowmeters may be placed downstream of any analyzer vent (a series analyzer flow path is permitted) unless the system can detect potential changes in restriction (i.e. sticking flowmeter), and

i) alert the operator of the problem which would require a new gas span and/or repair of the component causing the restriction, or

ii) use automatic compensation of the analyzer readout device for the change in restriction.

b) A change in restriction that will cause a 3 percent of point change in the analyzer response shall activate the alert system.

E. Analyzer Performance Specifications

1. Calibration Curve Uncertainty including Bias errors, Precision errors, and Historesis (Per test procedure):

a) 5% of point (i.e. True value of reading).

b) Below 100 ppmh HC or 0.40% CO the uncertainty specification need not apply.

c) If the analyzer prevents the operator from reading below 10 percent of full scale on the high scale, then the uncertainty specification need not apply to that portion of the high scale.

d) If necessary to obtain the desired accuracy at the low end of the CO scale, the uncertainty of the CO calibration curve above 6% CO may be expanded to 10% of point.

2. Resolution:

a) analog meters - 2.5% fs on each range

b) digital meters (last digit increment by 1)

i) xxxx ppmh

ii) x.xx% CO

3. Compensation:

a) Altitude compensation (mandatory): The analyzer shall have sufficient zero and span adjustment to allow the spanning of the analyzer at any altitude between 0 and 7000 feet. The external span adjustment may be limited in range as long as a clearly marked internal adjustment will make up the difference.

b) Compensated Systems (optional): (For systems that choose to use pressure and temperature compensation of analyzer read-out and span system)

i) The temperature compensation network shall provide accurate results over the ambient temperature range specified in Section G of this chapter as well as exhaust gas temperatures up to 49°C (120.2°F). (Units with heated sample cells are excluded from this requirement).

ii) The pressure compensation network shall provide accurate and linear results (analyzer read-out) over a pressure range of ± 2 inches HgG from the local barometric pressure. The system shall be capable of operation between 24 and 32 inches HgA. Test points about which the pressure shall be varied in order to ascertain the accuracy and linearity of the compensation network are 24.5, 28.5, and 30.0 inches HgA.

c) Non-compensated Systems (optional): For those analysis systems that claim pressure and temperature compensation is not necessary, the analysis system shall be tested to the specification outlined in step b) for pressure and temperature compensated systems.

d) For optional systems b) and c), all testing (unless noted) shall be conducted with those systems (b or c) active and operational.

4. Zero Drift:

a) ±2% fs L.S. for 1 hour

b) ±2% fs L.S. for 30 minutes if equipped with automatic zeroing system (auto zero must be disabled for zero drift check).

5. Span Drift: ±2% fs L.S. for 1 hour.

6. Noise (clean environment): ±0.5% fs L.S. (Total 1% peak to peak) (See Test Procedure)

7. Sample Cell Temperture:

a) It is preferred that the sample cell and gases (sample and span) immediately upstream of the sample cell be heated. If the sample cell is heated the minimum sample temperature shall be 49°C (120.2°F).

b) If the sample cell is not heated, the analysis system must compensate for temperature affects on the gas (sample or span) measurement process as in Section 3.

8. Interferences

a) Gases

	Analyzer	
	HC	CO
i) 14% CO_2	: 1.5% fs L.S. (RR = 37500)*	1.0% fs L.S. (RR = 1500)
ii) Saturated Water @ 40°C (101°F)	: 1.5% fs L.S. (RR = 20,000)	1.0% fs L.S. (RR = 800)
iii) 100 ppm NO_2	: 1.5% fs L.S. (RR = 50)	1.0% fs L.S. (RR = 100)

b) Electronic

i) RFI	: 1.0% fs L.S.

ii) VHF	: 1.0% fs L.S.
iii) Induction	: 1.0% fs L.S.
iv) Line Interference	: 1.0% fs L.S.
v) Line Voltage and Frequency Variation (90-130 v A.C.) (59-61 hz)	: 1.0% fs L.S.

The operation manual shall contain an easily identifiable warning recommending against the use of portable generating equipment to supply power for the analysis system unless the user verifies that the power generating equipment will maintain the voltage and frequency within the above specification under the load conditions experienced during analyzer use.

vi) Static Electricity (Analog meters only)	: 1 meter division or 2½% fs L.S. whichever is greater. (Determined at the lowest and dryest temperature used during the evaluation testing).

* RR = Rejection Ratio

9. Propane to Hexane conversion factor: The mean propane to hexane conversion factor for each analyzer sold as a pass/fail inspection analyzer shall be between 0.48 and 0.56 for each test point. The mean value shall be known at the 90% confidence level to at least two significant figures. The confidence interval shall not exceed a 0.01 increment in the correction factor. Due to the exceptional hang-up characteristics of hexane a laboratory quality sample/span system that bypasses the analyzers' sample/span system may be used. All components in the laboratory system that come in contact with the hexane gas used for determination of the factor shall be either clean stainless steel or teflon® (viton® valve seats are permitted).

F. Sample System Performance Specifications

1. Maximum Sample cell mean pressure difference between gas spanning and sampling : 4" H_2O

2. Maximum sample cell Pressure variation during sampling (pump pulsations) : 6" H_2O

3. Maximum sample cell mean pressure difference between normal flow and low flow indication : 4" H_2O

4. Response Time : 14 sec. maximum
Inlet of probe to 95% fs L.S. (@ low flow indication)
(See Test Procedure)

5. System Leakage:

a) The analyzer shall not be used if a leak(s) exists in the vacuum side of the system that causes a measurement error of greater than 3% of the true sample value.

b) The pressure side of the sample system shall be leak free as determined by a "bubble" leak-check method (not to be used in the field).

c) The vacuum side leak-check method shall consist of a comparison of the span gas response introduced through the span network to the response of the same span gas introduced through the probe and sample line. In the future with demonstrated and historical data, other leak-check techniques may be accepted or equivalent to the gas comparison leak-check.

d) The analyzer manufacturer shall provide a convenient system to introduce the span gas to the probe in a manner such that the pressure in the sample line during leak-checking is equal to or slightly below the pressure occurring in the sample line during testing. It is preferred that the leak checking equipment be mounted on the analysis system structure.

e) The analyzer manufacturer shall provide, in the operating manual, step by step leak-checking procedures including calculations.

f) Gas comparison leak-checks on the vacuum side of the system shall be performed every 180 hours (once a week). Abbreviated leak-checks (e.g. vacuum decay, etc.) may be used on a daily basis, if desired, but not as a substitute for the weekly gas comparison test.

g) The user (i.e. State, or Contractor, or owner/inspector) is responsible for implementing policies and procedures to insure that the leak-check procedures and frequencies are adhered to.

6. HC Hang-up:

a) The HC analyzer response to room air sampled through the probe and sample line shall be less than 20 ppm C6 prior to testing a vehicle or the test is void.

b) The analyzer manufacturer may provide an internal back flushing sequence or chemical (or catalytic) purification equipment (i.e., oil and impurity removal, etc.) for external compressed air back flushing in order to reduce the time required for hang-up checking.

c) A receptacle on the analyzer structure may be provided for the HC hang-up check to preclude the probe from sampling room air in close proximity to the floor.

d) The analyzer manufacturer shall provide, in the operating manual, step by step hang-up checking procedures.

e) The operation manual shall caution the operator that an excessively long time (5 to 10 minutes) to reduce the hang-up level to below the 20 ppm C6 HC level indicates that system maintenance may be required.

f) The user (i.e. State or Contractor) is responsible for implementing policies and procedures to insure that the hang-up procedures are conducted prior to every test.

g) For evaluation testing only, the hang-up level should be less than 20 ppm C6 within 10 minutes of beginning any hang-up check (including 2 hour sample) specified in the evaluation tests.

G. Operating Environment

1. The analysis system shall meet all system specifications required in Chapter VII under the following conditions (see Test Procedure):

a) Ambient Temperature: Between 35°F to 110°F

b) Ambient Relative Humidity:

i) Range of field operation: 0% to 100% condensing (i.e. raining or dense fog).

ii) The user shall prevent direct impingement of condensed ambient moisture (rain) on the analyzer (i.e. DO NOT LET IT RAIN ON THE ANALYZER).

iii) Range of Testing: 15% to 85%

iv) Maximum Test Point: 80% to 85% RH @ 105°F(±5°)
WARNING: Testing in environmental chambers at relative humidities above 85% with temperatures above 90°F may be HAZARDOUS to human life! The primary hazard is due to heat loading on the human body's cooling-system (i.e. perspiration effectiveness) leading to heat induced body disfunctions. Precautions should be taken to avoid overexposure. A secondary hazard is a potential electric shock hazard due to the high moisture content of the test cell.

2. The analysis system shall be able to be stored at any temperature between -20°F to 130°F with no adverse effects on subsequent analysis system performance.

H. Fail-Safe Features

1. Warm-Up

a) The analyzer must have a warm-up lock-out feature with indicators. No specific warm-up time is specified.

b) The lock-out feature shall prevent operation of the printer (if used) and read-out meter until the system is warmed up.

c) The lock-out feature shall be activated:

i) When system power is turned on. The lock-out shall stay on until the zero drift is stabilized. The manufacturer must condition the lock-out on analyzer parameters, and may not use clock time as a sole criteria to determine warm-up condition. Verification of proper zero stabilization is determined by observing the zero drift over a 5 minute period after the lock-out feature deactivates. The zero drift during this 5 minute period may not exceed one-half of the zero drift specifications in Section E. If digital sampling of the zero level is used, the sample rate shall be at least 10 hertz. Analog observation of zero drift is permissible.

ii) If the sample cell is heated and the cell temperature is less than that specified in section E.

2. Low-Flow

i) The analyzer must have a low sample flow indicator. Inspecting a vehicle when the low flow indicator is activated constitutes improper operation. The user (i.e. State, contractor, or owner/inspector) is responsible to insure proper operation.

ii) The low flow indicator shall be activated when the sample flow rate is decreased to a point that would not allow the analysis system to meet the response time specifications.

iii) The low flow indicator shall be prominently displayed, and shall be observable from at least 15 feet away.

I. System Correlation (on Raw Exhaust) to Laboratory Analyzers

1. All analyzers (comparison to NDIR Analyzer per Test Procedure)

a) Precision Test: $\Delta P \leq 5\%$
b) Slope Test: $0.95 \leq m \leq 1.05$
c) Ratio of Modal Ave: $0.90 \leq R \leq 1.10$

J. Manuals

1. Each analyzer shall be delivered with one each of the following manuals.

a) Easy Reference Operating Instructions

b) Operation Instruction Manual

c) Maintenance Instruction Manual

d) Initial Start-up Instructions

2. The manuals shall be constructed of durable materials, and shall not deteriorate as a result of normal use over a five year period.

3. The easy reference operating instructions:

a) shall include brief step by step instructions for

i) Gas Spanning

ii) Electrical Spanning

iii) Leak Checking

iv) Inspection testing with probe insertion, anti-dilution, HC hang-up, and reading test value instructions.

b) may be stenciled or decaled to the analyzer frame in a location convenient to the operator, may be printed on plastic flip-up cards attached by a ring or chain to the analyzer, or may use some other communication means that allows repetitive and convenient use of the instructions by the operator. All easy reference materials shall be attached to the analyzer.

4. The operating instruction manual must contain :

a) The analyzer model

b) A more detailed step by step sequence of pre-test procedures (span, leak check, probe insertion, HC hang-up etc.)

c) Sampling procedures

d) The operating manual shall provide to the operator more insight into the specific procedures than the easy reference instruction are capable of because of their brevity. It may be appropriate to include diagnostic instructions in the operating manual.

5. The maintenance manual must contain:

a) Name, address, and phone number of the manufacturer's customer service and maintenance center at the home office and nearest field office.

b) Name, address, and phone number of the nearest service center authorized to make warranty adjustments.

c) A technical description of the system.

d) A separate section that clearly outlines the required or anticipated maintenance schedule. The schedule shall be broken down into maintenance intervals such as weekly, monthly, etc.

e) A separate section that provides a step by step sequence for each maintenance requirement.

f) A list of replaceable items such as filters, probes, etc. with part numbers, and the estimated service life of each component (normal operation).

g) A list of recommended spare parts that the user should maintain.

h) Functional mechanical and electrical schematics.

i) The manufactuer's warranty provisions.

6. Each manual shall be attached to the analyzer in a manner that will:

a) allow convenient storage,

b) allow easy use, and

c) prevent accidental loss or destruction.

7. The manufacturer's service representative is responsible for logging all repairs performed by the manufacturer or their representative with appropriate description in the log book.

VIII. Additional System Specifications Recommended for Decentralized Inspection Programs (computer operation)

The following fail-safe features are specified in order to prevent improper operation of analysis systems used for decentralized systems. However, they could be useful in centralized systems as well. In general these features will probably require an on-board microprocessor. When using a microprocessor, an alpha numeric keyboard and readout may be substituted for various switches, buttons, or indicators specified in the following sections. Microprocessor units may also elect to print void test results instead of interlocking the printer. In that case, the word "VOID" must prominently and/or superimposed over the data. All valid test results must clearly indicate the validity of those results.

A. Automatic zero/span check

1. The analyzer shall not have any adjustments available to the operator for adjusting zero or span point for either the gas spanning operation or the electrical spanning operation. These adjustments shall be available in the anti-tampering box described in this chapter.

2. The analyzer shall have a selector switch or button (with indicator) labeled "gas span". Activation of the switch shall cause the analyzer to automatically perform the gas spanning sequence with flowing zero and span gas consistent with the requirements for the manual analyzer spanning system specified in Section D.7. of Chapter VII.

3. If the analyzer is equipped with multiple ranges, there shall be convenient controls or automatic sequence available to audit or service personnel to adjust or trim the scale factor between ranges. The adjustment shall be based on the analyzer's response to calibration gas concentration values. The concentration values shall be between 70 and 100 percent of each range. When trimming the scale factor, start on the highest range and work down. When spanning, start on the lowest range and work up.

4. The analyzer shall have a selector switch or button with indicator light labeled "electrical span". Activation of the switch will cause the analyzer to automatically perform an electrical zero and span operation consistent with the requirements for the analyzer manual spanning system specified in Section D.7. of Chapter VII.

5. The automatic gas spanning operation shall be completed as quickly as possible (preferably less than 90 seconds) once the "gas spanning" switch is activated.

6. The concentration of span gas shall be entered via switches or other convenient means to the following resolution:

HC = XXXX ppm propane
CO = X.XX% CO

The switches or interlock that allows the entering of the span gas values shall be in an anti-tamper box as described in this chapter.

7. When the analyzer is initially installed at a new sight, the analyzer gain for a proper gas span shall be automatically stored for future reference. If the adjusted span gain for any subsequent spanning operation exceeds 150 percent of the initial stored value, the analyzer readout shall be electronically driven to 100% of full scale, (or an error message displayed), the printer, if used, shall be prevented from printing, and an indication of analyzer malfunction shall be prominently displayed. If the adjusted span gain for any subsequent spanning operation exceeds 140 percent of the stored value, an indication to the operator of pending maintenance shall be provided.

8. If the adjusted span voltage changes by more than 20 percent of the most recent span voltage, the analyzer read-out shall be electronically driven to 100% of full scale, the printer if used shall be prevented from printing, and an indication of analyzer malfunction shall be prominently displayed.

9. The analysis system shall include suitable timers to insure that the spanning frequencies are met. The timing systems shall also prevent use of the analysis system by driving the readout devices to full scale (digital units may substitute an error message for the analyzer reading) and prevent the printer from printing. Performing the appropriate spanning operation shall automatically reset the timer for that specific type of operation regardless of the time elapsed since that operation was last performed. The options listed in the next Section (Section B. Automatic Leak-Check) may be used in lieu of a battery back-up for "power-off" time keeping.

10. The microprocessor system shall compute the equivalent hexane (HC) span set point based on the input propane value, and the analyzer propane/hexane conversion factor. The auditor shall have access to the computed value.

11. All features in Section D.7. of Chapter VII shall apply to the automatic span system.

B. Automatic Leak-Check

1. The sampling system shall have an automatic leak checking system for the vacuum side of the system.

2. The analyzer shall have a timer that will allow the analyzer to operate for 180 calendar hours (once per week) between leak checks. If after 180 hours the system is not leak checked, or the system fails a leak check, the analyzer readout shall be electronically driven to 100 percent of full scale (Digital units may substitute an error message for the analyzer reading), and the printer shall be prevented from printing. The following options are available in any combination:

i) Option 1: If a full leak check is performed every time the power is turned on, and an operating time clock insures that the leak check frequency is met in the event that the power is left on continuously, then an auxilliary power supply (i.e. battery) for the clock during power off is not necessary.

ii) Option 2: In lieu of a real time clock with battery back-up, the system may count the number of times the "power-on" switch (not the stand-by switch) is turned on. The weekly check will be assumed to have been met if the analyzer system requires a leak check (as specified) after every 6 times the power-on switch is turned on (i.e. leak check begins with the 7th time of power on). An operating time clock is necessary in the event the power is left on continuously.

3. Activation of the automatic leak-check system shall cause the analyzer to automatically perform (or check) a span sequence, automatically introduce span gas to the probe, compare the difference between the span and probe readings, and make a pass or fail determination.

4. A leak-check pass or fail indicator shall be prominently displayed.

5. All features in Section F.5. of Chapter VII apply to the automatic leak-check system.

C. Automatic Hang-Up Check

1. The analyzer shall have a selector switch or button (with indicator light) labeled "Hang-up Check" or "Purge."

2. Activation of the "Hang-up" switch shall cause the analyzer to automatically sample room air through the sample line and probe. The "Hang-up Check" system shall continue to sample room air until the HC response is less than 20 ppm C6.

3. Any combination of sampling room air and/or internal back flushing may be used to achieve a 20 ppm C6 HC level when sampling room air.

4. When HC level stabilizes below 20 ppm C6, a prominently displayed indicator shall notify the operator that it is permissable to begin a test sequence. The analyzer shall be precluded from beginning the test sequence until the hang-up check is met.

5. Activation of the "sample" switch shall be prevented unless a successful hang-up check has been performed since the last activation of the test sequence, and the HC analyzer has not experienced an HC level greater than 20 ppm C6, or

6. All requirements in Section F.6. of Chapter VII shall apply to the automatic HC hang-up check.

D. Automatic Read System

1. The analyzer shall have a selector switch or button (with indicator light) labeled "Sample" or "Test".

2. Activation of the "sample" switch shall cause the analyzer system to begin integrating or averaging the analyzer response 17 seconds after the switch is activated, and continue integrating the analyzer response to a flowing sample for the next 15 seconds. The sample and hold circuits can be either analog or digital. Digital sample rates shall be at least 10 hertz. If the manufacturer identifies that the response time to 99 percent of a step change is less than 17 seconds, the manufacturer may select any time between the 99 percent time and 17 seconds to begin the integration. If the manufacturer elects this option, the integration start time must be boldly visible on the front of the analyzer. Failure to meet this new response time during field audit checks will constitute a failure of the audit.

3. The analyzer read-out device shall display the integrated value, and hold the display until reset. An indicator light shall signal the operator when the integrated value is displayed. The automatic test sequence may interact with the automatic read system to reset the display at appropriate times or within the test sequence.

4. The analyzer shall be prevented from printing the integrated value until the "sample" switch is activated and the "sample" cycle is completed.

E. Dual Tailpipes

1. The system shall have the capability to automatically calculate the average reading for dual tailpipes.

2. The dual tailpipe system shall use integrated test values from the automatic read system for averaging.

3. Activation of the dual tailpipe system shall allow two activations of the automatic read system without activating the hang-up check interlock.

4. The dual tailpipe system shall display the average value on operator command, and hold the value until reset.

F. Automatic Test Sequence

1. The microprocessor must be capable of being programmed for the standard sequences listed in Table VIII-1. These test sequences do not cover all of the possible combinations that may exist. On the contrary, these sequences were limited in number specifically in an effort to standardize procedures and equipment.

2. The system must store the cutpoints for each mode of the test sequence used. The operator may only use State accepted criteria for selecting cutpoints. It is recommended that the following criteria be used.

a) Vehicle Model Year

b) Type of Vehicle

i) Light-Duty Vehicle

ii) Light-Duty Truck

iii) Heavy-Duty Gas Truck

c) Spare Channel (fuel type)

d) Spare Channel (Catalyst-non-catalyst, California-non-California)

3. Access to the test sequence programming, and cutpoint values and applications shall be limited to State Auditor by means of the anti-tampering provisions in this chpater.

4. The system must identify the integrated value for each mode, make a pass or fail decision on that mode, and either immediately print the results or store the results until the completion of the test sequence.

5. If the test sequence includes more than one mode, the system shall use the pass or fail decision from all applicable modes to determine an overall pass/fail determination.

Table VIII-1

Recommended I/M and 207(b)
Test Sequences *

Test Type	Test Mode: Non Idle	Test Mode: Idle
Pre-81**	-	Pass/Fail
Post-81*** (unloaded)	2500 RPM, Pass/Fail	Pass/Fail
Post-81 (loaded)	30 MPH, Pass/Fail	Pass/Fail

* Test sequences may be preceeded by any type of preconditioning desired if the sequence is performed manually. The Automatic test sequence feature in the analyzer need only follow the test modes described after the test sequence is initiated by the operator.

** Pre-1981 model year vehicles.

*** 1981 and later model year vehicles.

G. Printer

1. The analysis system shall have a printer that provides the consumer and the inspector (not required with Automatic Data Collection option) a receipt with the following information:

a) Date (the printer may use manually input values for the date).

b) Inspection Facility Number or Instrument Serial Number (value may be input manually).

c) Inspection Test Number (may be sequenced by initiation of Automatic Test Sequence).

d) Applicable cutpoints or standards for HC and CO for each test mode.

e) Integrated vehicle test values for HC and CO for each test mode.

f) An overall pass or fail indication as well as for each test mode.

H. Vehicle Diagnosis

1. For the purpose of vehicle diagnosis and/or repairs, the analyzer shall have a selector switch or button (with indicator light) labeled "Vehicle Diagnosis" or "Vehicle Repair".

2. Activation of the "Vehicle Diagnosis" switch shall allow the analyzer to continuously monitor the vehicle exhaust.

3. The printer, or any automatic data collection system, shall be prevented from operating anytime the analysis system is in a "Vehicle Diagnosis" status.

4. Auxilliary analog trend meters may be used provided that they are deactivated for inspections.

I. Anti Tampering

1. The anti-tampering feature shall be designed to prevent intentional tampering with the analysis system.

2. All switches or entry access for automatic zero/span check adjustments, anti-dilution limits, span gas concentration values, diagnostic switches, etc. shall be contained in a box or other tamper-proof mechanism with provisions for an inspector's seal. A gummed label with the inspectors initials and date which must be torn to gain access, or a braided wire and crimped lead seal (or similar device) would be sufficient for sealing.

3. The tamper-proof system must allow convenient access by an inspector.

J. System Diagnostic Testing

1. Switches or other devices for rendering any fail-safe or automatic feature inoperative for the purpose of diagnostic or performance checking of the analyzer are permitted.

2. These switches (or devices) must be contained in a tamper proof box(es) or other tamper-proof mechanism with provisions for a seal.

3. All analyzer systems must be shipped with all fail-safe and automatic features operating, and the defeat systems sealed.

IX. Optional Features For The Inspection Analyzer

The optional features listed are intended to provide more capability, flexibility, or convenience. They include automatic data collection (ADC), additional printer capability, anti-dilution equipment, loaded mode kit, and an engine tachometer. The first option (ADC) would generally require a computer operated analyzer. The remainder of the options are applicable to both the computer and manually operated analyzer.

A. Automatic Data Collection

1. The automatic data collection (ADC) feature may store data on a magnetic cassette tape, magnetic disc, or other storage medium.

2. Any external peripheral devices (phone line modems, external storage medium, etc.) should have an RS232 port.

3. Any external transmission of data should be coded in ASCII with a maximum of 80 column records.

4. Other coding, formating, and blocking should follow industry accepted standards.

5. The ADC storage medium should store data on at least 150 vehicles.

6. The stored data shall be available only to an appropriate inspector, and shall be protected by a seal (see anti-tampering).

7. A keyboard shall be available to allow the following types of data to be entered. As indicated, the system may automatically (Auto) enter certain data:

   a) Date (Auto)

   b) Vehicle license plate number

   c) VIN

   d) Vehicle type (LDV, LDT, HDG, etc.)

   e) Vehicle make

   f) Vehicle model

   g) Vehicle Model Year

   h) Emission Family Number (from emission label)

   i) Odometer

   j) Fuel type (gasoline, gasohol, methanol, ethanol, propane, hydrogen, spare channel, etc.)

k) Test Facility I.D. (Auto)

l) Facility Inspection Test Number (Auto)

m) Type of test. (Initial test, first retest, second retest, etc.)

n) Applicable cutpoints for HC and CO for each applicable test mode (Auto).

o) Anti-dilution decision criteria (ie. air pump, no air pump, etc.)

8. The processor shall enter the following data on the tape.

1) Integrated vehicle test values for HC and CO for each test mode.

2) An overall pass or fail indication for HC and CO as well as for each test mode.

B. [Deleted]

C. Anti-Dilution (Optional for all systems)

The anti-dilution feature can perform three useful functions: 1) most important, it can serve as an indicator of vehicle exhaust system leaks that would cause the measured emission values to be lower; 2) it can be used to identify dilution of the sample due to either probe placement or tailpipe extender leaks; and 3) it could potentially be used to insure decentralized operators actually insert the sample probe (or attach the extender), and actually measure vehicle exhaust samples.

1. The anti-dilution feature shall identify vehicle exhaust system leaks and sample dilution.

2. The preferred technique for identifying leaks is monitoring the CO_2 levels in the exhaust. Other techniques that can demonstrate improved sensitivity to leaks may be used.

3. At least three lower limit CO_2 values shall be capable of being used.

   a) no air pump

   b) air pump

   c) spare channel

4. The resolution of the CO_2 span gas values entered shall be, XX.X% CO_2.

5. The CO_2 values shall be entered by switches or other convenient means.

6. The CO_2 analyzer shall meet all of the analyzer specifications in Chapter VII between CO_2 values of 6% and 14%. (CO_2 interference specification does not apply). Specifications in Chapter VIII apply to computer analyzers.

7. If the CO_2 is less than the lower limit, the analyzer output shall be electronically driven to 100% of full scale (digital units may substitute an error message for the analyzer reading), the printer (if used) shall be prevented from printing, and an indication of exhaust system dilution shall be prominently displayed.

8. The analyzer operator shall be able to select one of the three lower limits.

9. The analyzer shall be prevented from reading auto exhaust until one of the three limits is selected.

10. If a printer is used, the CO_2 limit for the test shall be printed.

D. Loaded Mode Kit

The analyzer specifications in the previous chapters generally apply to an analyzer used for unloaded or idle testing. The analyzer designed for the unloaded test can usually be transformed into a loaded mode analyzer with suitable changes to the sample handling system. In some cases these changes could possibly be retrofitted in the field on analyzers originally manufactured as unloaded analyzers. The following items should be included in a loaded mode analyzer.

1. A refrigeration or ice bath water trap. The water trap must lower the sample gas temperature to 7°C (45°F). Suitable measurement devices and indicators must alert the operator on the status of the unit. No testing should be performed at sample temperatures above 7°C. With the manual system, the operator is responsible to insure that this criteria is met. The computer analyzer would need an interlock with the sample gas temperature measurement device in order to become responsible for proper procedures.

2. All components upstream of the refrigeration trap must be capable of running continuously at 1000°F inlet (to the probe) exhaust temperature. Some of the equipment that would possibly require upgrading for the higher temperature would include the tailpipe extender and connector, the probe, and the sample line.

3. The loaded mode analyzer may require additional sample filtration.

E. Engine Tachometer

The two speed idle test (see Table VIII-1) meaures emissions at idle and at an elevated engine speed, usually 2500 RPM. The standard idle emission test, in most cases, preconditions the engine at 2500 RPM. In some instances, it may be beneficial to have engine speed measurement capabilities included within the emission analyzer system. The tachometer should have the following features.

1. The tachometer accuracy should be stated in the maintenance manual.

2. For "propane gain" diagnostic work, tachometer accuracy should be ±30 RPM between 400 RPM and 1200 RPM. The precision or repeatability should be 5 RPM or less, and the resolution should be 1 RPM.

3. The preferred transducer is a clip-on magnetic induction pick-up.

4. The computer operated emission analyzer should monitor the engine speed during the high speed portion of the two speed idle test. If the engine speed exceeds selected limits during the test, the computer shall void the test.

X. Future Improvements for the Inspection Analyzer

A. Introduction

During the development of these specifications, several areas of emission analysis were identified that should be improved. Improvements in these areas have not been included in the specifications (and hence do not impact State adoption of the recommended specifications) because of either the cost or the lead time required to develop the improved technology. The staff feels, however, that those involved with emission measurements should be aware of the need for these improvements. The following discussions are directed mainly at the analyzer manufacturers in hopes of stimulating the necessary developments or improvements. The staff feels such improvements can be economically feasible by 1987.

B. Improvements in Water Removal

There are two forms of emission measurements. A "wet-basis" measurement is the form the exhaust leaves the tailpipe fully laden with moisture from the combustion of the fuel. Most NDIR type emission analyzers cannot accept this moisture, and still operate properly. Unless substantial improvements or breakthroughs are made in emission measurement equipment, it is expected that NDIR type analyzers will be used in the future. Therefore, practical systems must provide a method for removing the moisture before it enters the analyzer. If absolutely all of the water is removed from the sample, the measurement becomes a "dry-basis" measurement. The difference between a wet and a dry measurement of the same sample can be as much as 10 percent (dry is higher).

Practically all current field analyzers use a momentum type water trap. The moisture removal efficiency of this type of trap ranges from 0 to 100 percent depending on the ambient temperature and the sample temperature. Some state inspection lanes use a refrigeration trap which generally has a moisture removal efficiency between 98 to 100 percent. In order to allow for these variations in moisture removal efficiency, it was elected to base the 1984 Federal H.D. truck idle standard on a dry-basis measurement. For this same reason, it is expected that the projected 207(b) standards would be dry-basis values.

These decisions effectively consider all I/M inspection measurements as dry-basis measurements even though many may not be. In order to eliminate some of this measurement variation in the future, it is reasonable to expect that all measurements be taken on a truely dry-basis. Two techniques are suggested for dry measurements. The first is similar to portions of the loaded mode kit. Adoption of this improvement would be to remove a potential 7 to 10 percent variability in I/M measurements.

Analyzers manufacturered after January 1987 should include one of the following.

1. A refrigeration or ice bath water trap. The water trap must lower the sample gas temperature to 7°C (45°F). Suitable measurement devices and indicators must alert the operation on the status of the unit. No

testing should be performed at sample temperatures above 7°C. With the manual system, the operator is responsible to insure that this criteria is met. The computer analyzer would need an interlock with the sample gas temperature measurement device in order to become responsible for proper procedures.

2. Electronic compensation. Electronic correction to a "dry-basis" reading is permitted if the temperature and pressure of the sample after the water trap is measured and the sample is assumed to be saturated at the measured temperature. The water correction system must be deactivated for leak checks.

C. Improvements in HC Measurement

Non-dispersive Infrared (NDIR) HC analyzers used in I/M programs are limited in their ability to measure all of the hydrocarbons in the exhaust. Current NDIR analyzers tend to measure only straight chain paraffinic hydrocarbons, although they do have some response to aromatics and aldehydes. The lack of response to these non-paraffinic compounds is the primary reason why the Federal Test procedure changed from NDIR HC measurement to FID (flame ionization detector) HC measurement 8 years ago (1972).

Even though catalyst vehicles tend to produce more paraffinic hydrocarbons than non-catalyst vehicles, chromatographic analysis of gasoline-fueled engine exhaust indicates significant quantities of the non-paraffinic hydrocarbons exists even in catalyst vehicles. The very same compounds that current NDIR HC analyzers have difficulty in measuring.

Changes in fuel composition can also affect the composition of the hydrocarbons in the exhaust. An increase in aromatics components in the fuel as in unleaded premium gasoline will tend to increase the aromatic content of the exhaust hydrocarbons. A similar situation occurs with gasohol which tends to increase the content of aldehydes in the exhaust concentration. Since the NDIR HC analyzer has poor response to both aromatics and aldehydes, the current NDIR analyzers will generally show a decrease in hydrocarbons when the true hydrocarbon content as measured by an FID would generally remain about the same.

Considering these facts, one may question the necessity or the wisdom of HC measurements with an NDIR analyzer in an I/M program. Even though the NDIR HC analyzer does not measure all of the HC in the automobile exhaust, a reduction in the paraffinic hydrocarbon levels can in many cases be indicative of a reduction of the other classes of hydrocarbons. Further, the criteria for determining State cutpoints is the number of vehicle failures, and the reduction of just the paraffinic hydrocarbons from the failed vehicles still contributes to a reduction in ambient air hydrocarbons.

One may also question why an FID is not specified in the first place. The reason is that an FID is a complex piece of laboratory equipment that requires a mixture of hydrogen and helium for fuel, and purified air for an oxidizer. At this point, the staff is somewhat skeptical about the compatability of current FIDs in an I/M test environment.

In the past there has been no incentive to improve the field measurement techniques for HC measurements. Considering the possible impacts of fuel switching and the fact that if a program continues past 1987 the program may not be as effective as predicted in the SIP, the staff feels that the HC measurement techniques should be improved.

The improvements can be accomplished through better response characteristics of current NDIR's, or new less complex HC measurement techniques could possibly be developed. In order to provide an incentive for this advancement in technology, beginning in January 1987, it is recommended that all I/M analyzers correlate to an FID HC analyzer by the procedures provided. To assist in the degree of correlation that is technically feasible, it is recommended during the verification of current analyzer performance that an additional test be performed that compares the I/M HC analyzer to an FID. Review of the NDIR/FID correlation data generated by the accreditation procedures is recommended prior to the implementation of the 1987 specifications.

Analyzers produced after January 1, 1987 should correlate to an FID in the following criteria (see Test Procedure):

1. Precision Test: $\Delta P \leq 5\%$
2. Slope Test: $0.317 \leq m \leq 0.350$
3. Ratio of Modal Ave: $1.80 \leq R \leq 2.20$

XI. Evaluation Procedures

The test procedures in this chapter are presented to provide a consistent interpretation of the specifications. Although the procedures do provide a step by step sequence, and it is expected that the evaluator follow that sequence; they are not a substitute for common sense or good engineering judgment. Some analysis system designs may simply not be amenable to certain portions of certain test procedures. Further, there may be ways to simplify or combine certain test procedures. In those cases, the evaluator should review the procedure as written, determine the important conceptual aspects and parameters of the procedure, and then use engineering judgment in testing the analyzer.

The basic test procedure should be performed in a laboratory that has experience in automotive emission testing. The general testing should be conducted at an ambient temperature between 68°F and 86°F. Section G requires certain test procedures to be conducted at other ambient temperatures.

If either of the non-gas spanning alternatives are used (See Chapter VII, Section D.7.), only one gas span operation is permitted for the entire Chapter XI procedure, unless otherwise noted. This single gas spanning operation shall take place during the initial start-up procedure. Electrical span will be substituted for all other gas spanning operations. Analytical gases, of course, will be required for check out of the system.

The procedures as written are generally independent of tolerance specification values. Following each test procedure, a reference value corresponding to the values given in Chapter VII through X will be given in parenthesis.

A. Traceability of Analytical Gases

The traceability of analytical gases may or may not be part of the analyzer manufacturer's responsibility. The choice belongs to the state. However, it is recommended that the analyzer manufacturers not be held responsible. Further, gas manufacturers should meet certain performance standards and be accredited as acceptable vendors, or the state should provide a distribution service.

The traceability of all gases used in the I/M program is of course important. Traceability implies not only blending, but analyzing the gases properly. Although operating the analysis equipment properly seems like a trivial task, some very prominent laboratories have sometimes been embarrassed by subsequent review of their procedures and analysis of their blended gases.

In order to provide the automobile manufacturers with what EPA/OMSAPC considers proper traceability procedures, the Emission Control Technology Division (ECTD) of EPA is publishing a Recommended Practice for Assuring Gas Traceability to NBS. This procedure, which is a compilation of internal EPA procedures, is applicable to I/M analytical gases.

The entire traceability procedure may involve more equipment than a state may wish to become initially involved with. A minimum recommendation for I/M programs is that each gas blender or certifying laboratory that is allowed to supply gases for pass/fail I/M systems should follow the ECTD procedure. The next step would be a continuing quality-audit of each supplier by the state using the correlation portion of the traceability procedure.

B. Gas Cylinder Specifications

No test procedures required.

C. Durability Test Procedures

1. Vibration and Shock Test Procedure

The vibration and shock test procedure is designed to evaluate the ability of the analyzer to tolerate moderate use in a service facility. Although a simple span test is performed, the real test of the analyzer is the ability of the analyzer to meet the remaining performance checks to follow this test.

a) Equipment Required

i) Candidate instrument.

ii) One span gas between 70 and 90 percent of full scale on the low range, and bottled zero gas.

iii) A special test floor 6 feet by 10 feet. The top of the floor shall be elevated 2 inches off the test facility floor. The floor shall consist of an expanded metal grating with diamond shape openings measuring 1 x 3.7 inches or equivalent. The length of the floor in the direction of the "short way of the diamond" shall be 10 feet.

b) Test Sequence

i) Warm up the analyzer.

ii) Span the analyzer on the low range with the span gas per the manufacturer's recommendations (on the test floor).

iii) Record the zero response and the span response.

iv) Roll the instrument the entire length of the test floor in the direction of the "short way of the diamond", and off the end of the test floor onto the facility floor.

v) Pull the analyzer back onto the test floor.

vi) Repeat steps iv) and v) a total of six times.

vii) Check the zero response, and if necessary adjust the zero.

viii) Check the gas span response (do not adjust the analyzer span).

ix) Record the zero response and the span response.

c) Calculations

i) Subtract the zero response from the span response in step b) iii)---(span before).

ii) Subtract the zero response from the span response in step b) viii)---(span after).

iii) Subtract the value calculated in step c) ii) from the value calculated in step c) i)---(span shift).

d) Acceptance Criteria

i) If the value calculated in step c iii) is less than or equal to the vibration and shock span shift specifications, then the vibration and shock performance is acceptable.

ii) Reference value: 2%

2. Sample Line Crush Test Procedure

The sample line crush test is to be repeated under the "operating environment" testing. If space is a problem in the environmental chamber, after stabilization, the sample line can be removed from the chamber to perform the crush test. If the line is removed from the chamber, the crush test must be performed and the line returned to the chamber within 3 minutes.

a) Equipment Required

i) Candidate instrument.

ii) One span gas between 70 and 90 percent of full scale on the low range, and bottled zero gas.

iii) One vehicle with at least 4000 pound curb weight.

b) Test Sequence

i) Stabilize the sample line at the prevailing ambient temperature.

ii) Warm up the analyzer. Do not turn on the sample pump.

iii) Span the analyzer with the analytical gases.

iv) Leak-check the system.

v) Stretch out the sample line across a solid (concrete etc.) floor.

vi) Drive across the sample line so that at least one front and one rear vehicle wheel passes over the sample line.

vii) Back over the sample line so that at least one front and one rear vehicle wheel passes over the sample line.

viii) Repeat steps vi) and vii) twice.

ix) Leak-check the system.

x) Check for "low flow" indication.

xi) Check for visible failures, kinks, deterioration, etc.

c) Calculations
(none)

d) Acceptance Criteria

i) If the system passes the leak check (step ix), does not indicate a "low flow" condition (step x), and shows no sign of permanent deformity (step xi), then the crushability performance of the sample line is acceptable.

3. Sample Handling Temperature Effect

a) Equipment Required

i) Candidate instrument with tailpipe extender.

ii) Catalyst equipped vehicle.

iii) Thermocouple read-out device.

iv) Type "J" or type "T" thermocouple (1/16 inch diameter MgO shielded and grounded).

v) One HC span gas between 70 and 90 percent of full scale on the low range, and bottled zero gas.

vi) Associated fittings.

b) Test Sequence

i) Locate a point approximately 1 inch upstream from the end of the probe, and weld a thermocouple boss on the extender (top side when installed on vehicle).

ii) Install the thermocouple into the extender to a distance approximately half-way between the extender wall and the sample probe.

iii) Warm up the analyzer.

iv) Span the analyzer with the analytical gases.

v) Leak check the system.

vi) With the vehicle running, locate a position away from the vehicle to avoid vehicle contamination, and measure the background HC levels with the sample system. Record the background HC levels.

vii) Install the extender on the vehicle.

viii) Adjust the vehicle to elevate the exhaust gas temperature (as measured by the thermocouple) to at least 300°C (572°F)and not more than 360°C (680°F).

ix) As soon as the exhaust gas has stabilized between 300°C and 360°C, start a timer and begin sampling.

x) After twenty (20) minutes at the temperature in step viii), remove the probe or extender, and simultaneously start another timer.

xi) Immediately move the probe or extender to the location previously used to measure background HC, while continuing to sample room air and simultaneously start a timer.

xii) Continue to sample room air until the analyzer response is 20 ppmh. Record the elapsed time to 20 ppmh.

xiii) Introduce zero gas into the analyzer through the gas spanning system. Record the response.

xiv) Introduce span gas into the analyzer through the gas spanning system. Record the response.

xv) Leak check the system.

xvi) Check for "low flow" indication.

xvii) Check for visible failure, melted or deformed parts, deterioration etc.

xviii) When the testing is completed, remove the thermocouple and cap the boss with a leak proof cap.

c) Calculations

i) Compute the difference in span response between step b) xv) and b) iv) --- (span drift).

d) Acceptance Criteria

i) The value computed in c) i) must be less than the span shift specifications. (Reference value: 2%).

ii) The system must pass the leak check.

iii) A low flow condition shall not be indicated.

iv) No portion of the system shall show signs of heat damage.

v) The elapsed time recorded in c)xii) shall be less than the HC hang-up specifications. (Reference value: 10 minutes).

vi) If the above criteria are met, then the high temperature performance of the system is acceptable.

4. Filter Check and Hang-up Test Procedure

The filter check procedure consists of two phases - a 2 hour check, and a check to determine the useful life of the filter. It is intended that all subsequent system check procedures are to be conducted with a filter and sample system that have experienced at least 2 hours of exhaust sample as defined in this procedure. Therefore, the second part of the filter test may be performed after the other tests are complete if a log of sampling time during the other tests is maintained. If during subsequent testing, a low flow indication occurs due to filter loading, the filter may be changed, the filter life recorded, and testing may continue with a new filter. After 20 hours of sample through one filter, the test may be discontinued.

a) Equipment Required

i) Candidate instrument.

ii) Test vehicle that can create a hydrocarbon sample of at least 1500 ppmh with a spark plug wire removed or the choke partially closed.

iii) Clean sample filter.

iv) One span gas between 70 and 90 percent of full scale on the low range, and bottled zero gas.

b) Test Sequence

i) Install a clean sample filter.

ii) Warm up the analyzer.

iii) Span the analyzer with the analytical gases, and leak check the system.

iv) With the vehicle running, locate a position away from the vehicle to avoid vehicle contamination, and measure the background HC levels with the sample system. Record the background levels.

v) Attach the tailpipe extender to the vehicle.

vi) Insert the probe into the extender and begin sampling.

vii) Begin the vehicle malfunction.

viii) As soon as the emissions exceed 1500 ppmh, begin a timer.

ix) Maintain the HC level above 1500 ppmh, and sample the vehicle for two (2) hours.

x) During the two hours monitor the "low flow" indication.

xi) After two hours, remove the probe or extender, and simultaneously start another timer.

xii) Immediately move the probe or extender to the location previously used to measure background HC. If the analyzer has an HC hang-up check cycle, immediately begin the check cycle.

xiii) Continue to sample room air until the analyzer response is 20 ppmh. Record the elapsed time to 20 ppmh.

xiv) Introduce zero gas into the analyzer through the gas spanning system. Record the response.

xv) Introduce span gas into the analyzer through the gas spanning system. Record the response.

xvi) Leak check the system.

xvii) Alternatives: 1) at this point the filter testing may be suspended in order to complete the other tests. A log book of sampling time must be kept for the other tests, or 2) reinsert the probe into the extender, and continue testing until the "low flow" system activates or until 20 hours of sample time is reached (whichever occurs first), or 3) repeat the 2 hour filter check at the end of the performance testing of the analyzer, then continue testing until the "low flow" system or 20 hour criteria are met.

xviii) Record the elapsed time to "low flow" indication (if appropriate).

c) Calculations

i) Compute the difference in span response between step b) xv) and b) iii) —— (span drift).

d) Acceptance Criteria

i) The value computed in c) i) must be less than the span shift specifications. (Reference value: 2%).

ii) A low flow condition shall not occur during the 2 hour check.

iii) The elapsed time recorded in c) xiii), shall be less than the HC hang-up specifications. (Reference value: 10 minutes).

iv) If the above criteria are met, then the performance of the filter is acceptable.

v) If the total elapsed time to "low flow" activation is not less than 70 percent of the analyzer manufacturer's estimate of sample life-time of the filter, the manufacturer's estimate is acceptable. If the elapsed time is less than 70 percent of the estimate, the manufacturer's estimate shall be revised downward.

D. Design Requirement Inspection and Test Procedures

1. Useful Life: No test procedure.

2. Name Plate: Visual observation.

3. Sample System:

a) Visual observation.

b) Visual observation.

c) Visual observation.

d) See "Analyzer Gaseous Interference and Noise Test Procedure," Chapter XI, Section E.8.

e) i) Statement by analyzer manufacturer on partical size and element lifetime.

ii) See "Filter Check and Hang-Up Test Procedure." (Chapter XI, Section C.4.)

4. Sample Pump: No test procedure.

5. Sample Probe: Test procedures self-explanatory or features can be determined by visual observation.

6. Sample Line:

a) Flexibility Test Procedure: Perform the normal motions required to use the sample line for testing vehicles. Perform this test at the lowest environmental temperature used for check out under Chapter XI procedures. Make a determination about whether the sample line can be used without a great deal of difficulty at the condition tested. If it is determined that the sample line is not sufficiently flexible, then the manufacturer may suggest more objective test procedures and/or more data to demonstrate compliance.

b) Self-explanatory Test Procedure.

c) Visual observation.

d) Statement by analyzer manufacturer.

7. Analyzer Spanning System Test Procedure: The performance and acceptance of the spanning system will generally be determined by the system's performance on the other test procedures conducted during the evaluation procedures, and visual observation of the equipment features. In other cases (such as event timers), the test procedures are self-explanatory, and are not listed. The evaluation of the test value integration will take place as part of the correlation testing in Section I of this chapter.

8. Analyzer Ranges: Visual observation.

9. System Grounding: Visual observation and manufacturer's instructions to service representatives.

10. System Vents: If restrictions downstream of the analyzer exit are apparent, a test procedure shall be devised that evaluates the analyzer performance under restricted conditions. Test Procedures E.3.a) (Altitude Compensation) and F.1. (Sample Cell Pressure Variation, Low Flow, and Response Time) shall be used for guidance.

E. Analyzer Performance Test Procedures

1. Calibration Curve Test Procedure

a) Equipment Required

i) Candidate instrument

ii) Seven or more calibration gases for each range of each analyzer roughly equally spaced over each range.

iii) Zero gas

iv) Associated valves and fittings

b) Test Sequence

i) If necessary, follow the manufacturer's instructions for initial start-up and basic operating adjustments.

ii) Warm up the analyzer

iii) Zero the analyzer with the zero gas

iv) Span the analyzer with one of the calibration gases. The span point should be approximately 80 to 90 percent of full scale of the low range

v) Recheck the zero. If the zero has shifted, repeat steps iii), iv), and v) a maximum of one more time.

vi) Do not adjust the zero or span controls on the analyzer for the remainder of the test.

vii) Introduce the calibration gases in ascending order of concentrations beginning with the zero gas. Record the analyzer response to each concentration value.

viii) After the highest concentration has been introduced and recorded, introduce the same calibration gases to the analyzer in a descending order. Include the zero gas. Record the response of the analyzer to each gas. Record negative zero responses (if any) as they occur as negative values.

ix) Repeat steps vii), and viii) a total of five times.

c) Calculations

i) For hydrocarbon analyzers, compute the hexane equivalent (ppmh) of each calibration gas by multiplying the concentration value in ppm propane (ppmp) by the propane/hexane conversion factor listed on the analyzer.

ii) Compute the standard deviation(s) and mean($\bar{x}$) of the analyzers response for each concentration of calibration gases. Include both upscale responses and downscale responses to the same calibration gas. Zero may be a special case and not amenable to the calculations.

iii) For all concentration values except the highest value, multiply the standard deviation(s) by a factor (K) of 2.5.

iv) Multiply the standard deviation(s) of the analyzers response to the highest concentration by a K factor of 3.5.

v) Compute the following for each concentration

1) $y_1 = \bar{x} + Ks$

2) $y_2 = \bar{x} - Ks$

vi) Compute the uncertainty(U) of the calibration curve for each concentration by:

$$U = \frac{\text{concentration value} - y_i}{\text{concentration value}} \times 100$$

where i = 1, or 2 U ±

d) Acceptance Criteria

i) Identify the maximum uncertainty for each range.

ii) If the maximum uncertainty is less than or equal to the uncertainty specification (Chapter IV, Section E), (plus or minus), the calibration curve is acceptable. If the uncertainty is greater than specification, the calibration curve is not acceptable. (Reference values: 5% of point above 100 ppmh and 0.4% CO, 10% of point above 6% CO is permissable if necessary)

iii) If the calibration curve is not acceptable, then the instrument manufacturer should undertake an engineering study to identify the cause of the problem prior to continued testing or introduction of the analyzer to the commercial market.

iv) After the cause of the problem is identified and the analyzer is repaired or adjusted this test should be repeated.

e) Repeat steps b), c), and d) for each range of the analyzer.

2. Analyzer Resolution

a) Analog Meters: The resolution is determined by the interval of the smallest graduation of the meter face for each analyzer range.

b) Digital Meters: The resolution is determined by the increment of the least significant digit of the meter readout for each range.

3. Compensation Test Procedures

a) Altitude Compensation Test Procedure (not required for analyzers with Spanning Alternative, 1 or 2)

i) Equipment

1) Candidate instrument.

2) One pressure gauge or manometer that reads in absolute pressure (e.g. 20 to 32 in. HgA) with 1% accuracy.

3) One differential pressure gauge (0 to 15 inches of water).

4) One flowmeter (0-20 cubic feet per hour (CFH)).

5) Two needle valves.

6) One vacuum pump (greater than 20 CFH@ 24 in. HgA).

7) One span gas 70 to 90 percent of full scale on the low range.

8) One Tedlar sample bag.

9) Associated lines and fittings (non-reactive).

ii) Test Sequence

This procedure is written around parallel HC and CO analyzers, and should be performed on each analyzer. If the analyzers are in a series configuration, then an additional pressure gauge(s) will be required, but the test can be performed on both analyzers at the same time.

If the analyzer manufacturer states in writing that the structural integrity of the sample cell will not withstand the pressure differential associated with this test procedure at 24 inches of HgA, the altitude check must be made in an altitude chamber. In an altitude chamber only steps 8), 9), 10), 14), 15), 16) and 20) need be performed at the pressures specified in step 13) and 18).

1) Identify the sample line entering the sample cell of each analyzer.

2) Install a tee fitting in the sample line immediately upstream of the sample cell (as close as practical). Install the tee with branch pointing up.

3) Immediately upstream of the tee install one of the needle valves.

4) Identify the exhaust line from the sample cell and install two tees or a 4-way cross fitting in the line with the branches pointing up.

5) Downstream of the tees or cross fitting install the flow meter.

6) Attach a differential pressure gauge to the tee upstream of the sample cell and one of the exhaust tees. Attach one gauge across each analyzer in a series system.

7) Attach the absolute pressure gauge to the second exhaust tee.

8) Warm up the analyzer.

9) Check for leaks.

10) Sample room air through the sample line with the needle valve wide open.

11) Record the sample cell exhaust flow rate, the differential pressure across each analyzer, and the absolute pressure.

12) Attach the second needle valve after the flowmeter.

13) Adjust both the needle valves to obtain an absolute pressure of 31 inches of HgA, the sample differential pressure recorded in step ii), and a flow-rate of not less than 2 cfh.

14) Fill the sample bag with the span gas, and introduce the span gas from the bag into the sample line.

15) Use the analytical gases to set the zero and span of the analyzer. Note if internal adjustments were required to span the analyzer.

16) Return to sampling room air.

17) Attach the vacuum pump to the exhaust line after the second needle valve with an appropriate length of line, and open both needle valves.

18) Turn the vacuum pump on, and adjust both needle valves to obtain an absolute pressure of 24 inches of HgA, the same differential pressure recorded in step 11), and a flow rate approximately the same as recorded in step 11).

19) Refill the sample bag if necessary, and introduce the span gas into the sample line from the bag.

20) Use the analytical gases to set the zero and span of the analyzer. Note if internal adjustments were required to span the analyzer.

iii) Calculations (none)

iv) Acceptance Criteria

1) If the analyzer can be spanned properly in steps ii) 15), and ii) 20, and the technique required to span the analyzer under these conditions is identified in the owner's manual, then the altitude compensation network is acceptable.

b) Pressure and Temperature Compensated Analyzer Test Procedure

i) Testing concepts: This test procedure is to be performed in order to identify the performance of any pressure or temperature compensation systems under the various environmental conditions that may be encountered during vehicle inspection testing. In general, temperature compensation will be evaluated during the basic check-out (68°F to 86°F) and during the more hostile environmental temperature tests specified in Section G. No other special testing would normally be necessary.

In order to evaluate pressure compensation systems, additional testing is necessary. If the analyzer manufacturer can make a case that testing the pressure compensation system in a manner similar to the procedure specified in Chapter V Section E.3.a) (altitude compensation) will represent actual analysis system operating conditions in the field, then that procedure (E.3.a) may be used for check-out. If a sufficient case cannot be made, and a suitable alternative test procedure cannot be determined, then performance evaluations of the pressure compensation system must be carried out in an altitude chamber. The pressure compensation test shall be conducted at each environmental temperature condition specified in Chapter V. The tests shall be performed on each range of each analyzer.

ii) Test conditions: The test conditions shall consist of three basic barometric pressures about which excursions in pressure shall be made. The values are:

Basic Test Point (inches HgA)	Excursion Points (inches HgA)
24.5	24.0, 26.5
28.5	26.5, 29.5
30.0	28.5, 31

iii) Test Sequence

1) Identify the concentration value that provides the greatest uncertainty in measurement as determined by Test Procedure E.1). Obtain a calibration gas at that level (same bottle if possible).

2) Set up the test equipment for one of the three test points.

3) Warm up the analyzer.

4) Gas span the analyzer with a different calibration gas between 80 and 90 percent of full scale on the low range and bottled zero gas. An electrical span would not be substituted for the gas span in this step.

5) Leak check the system.

6) Alternately introduce zero gas and the calibration gas identified in step 1) through the sample probe until a total of three readings are obtained and recorded for each test step.

7) The test steps for the 24.5 in HgA test point are:

Test Step	Action
24.5	gas span
24.0	3 readings
24.5	3 readings
26.5	3 readings
24.0	3 readings
26.5	3 readings
24.5	3 readings
24.0	3 readings
24.5	3 readings
26.5	3 readings

8) Repeat steps 4) through 6) at the 28.5 inch HgA test point. The test steps for this test point are:

Test Step	Action
28.5	gas span
26.5	3 readings
28.5	3 readings
29.5	3 readings
26.5	3 readings
29.5	3 readings
28.5	3 readings
26.5	3 readings
28.5	3 readings
29.5	3 readings

9) Repeat steps 4) through 6) at the 30.0 in. HgA test point. The test steps for this test point are:

Test Step	Action
30.0	gas span
28.5	3 readings
30.0	3 readings
31.0	3 readings
28.5	3 readings
31.0	3 readings
30.0	3 readings
28.5	3 readings
30.0	3 readings
31.0	3 readings

iv) Calculations

1) For each test point, compute the standard deviation(s) and mean ($\bar{x}$) for the 9 readings obtained at each pressure level.

2) Multiply each standard deviation by a K factor of 2.6.

3) For each pressure level at each test point, compute the following:

$$y_1 = \bar{x} + Ks$$

$$y_2 = \bar{x} - Ks$$

4) For each pressure level at each test point, compute the uncertainty (U) of the measurements based on the calibration gas used in step iii) 6) from:

$$U = \frac{\text{concentration value} - y_i}{\text{concentration value}} \times 100$$

where $i = 1, 2$

v) Acceptance Criteria

1) Identify the maximum uncertainty

2) If the maximum uncertainty is less than or equal to the uncertainty specification (Chapter VII, Section E), (plus or minus), for the basic analyzer calibration curve, the pressure compensation is acceptable. If the uncertainty is greater than specification, the pressure compensation is not acceptable. (Reference Values: 5% of point above 100 ppmh and 0.4% CO, 10% of point above 6% CO is permissable if necessary).

3) If the pressure compensation is not acceptable, then the instrument manufacturer should undertake an engineering study to identify the cause of the problem prior to continued testing or introduction of the analyzer to the commercial market.

4) After the cause of the problem is identified and the analyzer is repaired or adjusted this test should be repeated.

vi) Repeat steps iii), iv), and v) for each range of the analyzer.

c) Non-Compensated Systems

i) If an analyzer manufacturer claims that the measurement uncertainty specifications (Chapter VII, Section E.) can be met without pressure and/or temperature compensation, this claim can be verified by the test procedure in Section E. 3.b) of this Chapter. (Reference Values: 5% of point above 100 ppmh and 0.4% CO, 10% of point above 6% CO is permissable if necessary).

4. Analyzer Zero and Span Drift Test Procedure
(See Test Procedure Section H.1.a), Warm-up Lock-out Test Procedure).

a) Equipment Required

i) Candidate instrument.

ii) One span gas between 70 to 90 percent of full scale on the low range.

iii) One cylinder of zero gas.

iv) One chart recorder (one megohm impedance or greater) with approximately a 10 to 12 inch wide chart.

b) Test Sequence

i) Begin the test sequence with an analyzer that is turned off, and has stabilized at the prevailing ambient temperature for at least 3 hours.

ii) Remove the analyzer's protective cover.

iii) Locate the meter readout and attach leads from the readout terminals to the chart recorder. Deactivate the automatic zero on auto zeroing models.

iv) Reinstall the protective cover.

v) Turn on the analyzer.

vi) Select a voltage range on the chart recorder so that full scale of chart recorder equals full scale voltage of the analyzer meter on the range under test.

vii) The chart recorder must indicate both negative and positive zero drift. If necessary, offset the chart recorder zero 5 units up scale.

viii) As soon as the warm-up lock-out feature deactivates, zero and span the analyzer with the analytical gases per manufacturer's operating instructions, and start the chart recorder at a minimum chart speed of 0.5 inches per minute.

ix) Do not adjust the analyzer or recorder controls (zero or span) for the remainder of the test.

x) Reintroduce zero gas (if not done already) and start the test.

xi) Mark the chart paper indicating the zero response, the span response, and the start of the test.

xii) Flow zero gas through the analyzer for one hour. (30 minutes for automatic rezeroing units.)

xiii) Introduce the span gas to the analyzer (do not adjust the equipment).

xiv) Reintroduce the zero gas to the analyzer (do not adjust the equipment).

xv) Reintroduce the span gas to the analyzer (do not adjust the analyzer).

xvi) Flow span gas through the analyzer for one hour.

xvii) Reintroduce zero gas to the analyzer.

c) Calculations

i) Compute the difference (as a percent of full scale chart deflection) between the analyzer zero response for the first span check (step b)viii)) and the zero response after the 1 hour span check (step b) xiv)) —— (zero drift).

ii) Locate on the chart the maximum and minimum analyzer zero response during the first 1 hour period (step b) xii)).

iii) Compute the difference (as a percentage of full scale chart deflection) between the analyzer zero-response for the first span check (step b) viii)), and the maximum zero response and then the minimum zero-response as identified in step c) ii) —— (zero drift).

iv) Compute the analyzer span-response at the 1 hour span check as the difference between the chart reading of the span gas (step b) xiii) and the chart reading of the zero gas (step b) xiv)) —— (span response).

v) Locate on the chart the maximum and minimum chart reading during the one hour span period (step b) xvi)).

vi) Compute the difference (as a percentage of full scale chart deflection) between the analyzer zero-response immediately prior to the one hour span period (step b) xiv)), and the maximum and minimum span chart readings identified in step c) v) —— (span response).

vii) Compute the difference (as a percentage of full scale chart deflection) between the span chart deflection at the end of the 1 hour span, and the zero-response after the 1 hour span —— (span response).

viii) Compute the difference (as a percentage of full scale chart deflection) between the span chart deflection immediately prior to the start of the one hour zero test (step b) viii)) and the zero-response just prior to that span check --- (span response).

ix) Compute the difference (as a percent of full scale chart deflection) between the zero-response just prior to the start of the 1 hour span (step b) xiv)), and the zero-response just after the 1 hour span (step b) xvii)) —— (zero drift).

x) Compute difference (as a percentage of full scale chart deflection) between the following span responses in step c):

(vi max) to (iv)	span drift
(vi min) to (iv)	span drift
(vii) to (iv)	span drift
(viii) to (iv)	span drift

d) Acceptance Criteria

i) If each value computed in steps i), iii) max, iii) min, and ix) is less than or equal to the specifications listed for zero drift, the zero drift of the analyzer is acceptable. (Reference value: ±2% fs L.S.)

ii) If each value computed in step x) is less than or equal to the specifications for span drift, the span drift of the analyzer is acceptable. (Reference value: ±2% fs L.S.).

5. Analyzer Span Drift Test Procedure

(See Analyzer Zero and Span Drift Test Procedure, E.4.)

6. Analyzer Noise Test Procedure

(See Analyzer Gaseous Interference and Noise Test Procedure, E.8.)

7. Analyzer Sample Cell Temperature Test Procedure
(See Test Procedure Section H.1.a), Warm-up Lock-out Test Procedure).

a) Equipment Required

i) Candidate instrument.

ii) Thermocouple readout device.

iii) Type J or type T thermocouple.

b) Test Considerations

i) The sample cell test procedure may be run concurrently with the zero/span drift test or any other test that begins with an analyzer that is not warmed up.

ii) It is recommended that the test equipment remain hooked up to the analyzer for the duration of the analyzer check out, and the temperature of the sample cell should be monitored from time to time.

c) Test Sequence

i) Locate on the sample cell a point, based on engineering judgement, that would be the coldest point.

ii) Attach a thermocouple to the sample cell at the location identified in step i).

iii) Conductive, convective, and radiation losses must be considered in the selection of the location, and in the manner of thermocouple attachment.

iv) Stabilize the analyzer at the prevailing ambient temperature for at least 3 hours.

v) Record the sample cell temperature.

vi) Turn on the analyzer.

vii) As soon as the warm-up lock out feature is deactivated, record the temperature of the sample cell.

viii) Immediately switch to sample ambient air (or analytical gas at the ambient temperature) through the sample line.

ix) Monitor the sample cell temperature over the next 5 minutes.

x) Record the lowest sample cell temperature during the 5 minute period.

d) Calculations
(None)

e) Acceptance Criteria

i) If the temperature recorded in step c) v) is approximately the same as the ambient temperature, the analyzer is properly stabilized.

ii) If the temperatures recorded in step c) vii) and step c) x) are equal to or greater than the specifications for sample cell temperature, the sample cell temperature is acceptable. (Reference value: 49°C (120.2°F).)

iii) While monitoring the sample cell temperature during the analyzer check-out procedure, if the temperature is less than the specifications when concentration data (span or sample) is read, the acceptance in step ii) is void. (Reference value: 49°C (120.2°F).)

8. Analyzer Gaseous Interference and Noise Test Procedure

a) Equipment Required

i) Candidate instrument.

ii) One high impedence (1 megohm or greater) digital voltmeter with at least 4½ digit resolution. Generally, a 2 volt (1.9999 v) and a 20 volt (19.999 v) scale will be adequate. A chart recorder of similar impedence, resolution, and scaling may be used in place of a voltmeter.

iii) One calibration gas with approximately 14% CO_2 and the balance N_2.

iv) One steam generator.

v) One mixing chamber with probe attachment, dilution valve, and chamber air temperature readout system.

vi) One calibration gas with approximately 100 ppm NO_2. The NO_2 value must have been checked within 48 hours of the start of the testing sequence with a chemiluminescent analyzer meeting the specifications of 40 CFR 86 Subpart B, D, or N.

vii) One span gas between 70 and 90 percent of full scale on the low range, and bottled zero gas.

viii) Tedlar sample bags.

ix) Associated lines and fittings (non-reactive).

b) Test Sequence

i) Remove the analyzer's protective cover.

ii) Locate the meter readout and attach the voltmeter or chart recorder leads to the meter terminals.

iii) Reinstall the analyzer's protective cover.

iv) Temporarily bypass the water trap.

v) Warm up the analyzer.

vi) Introduce the span gas to the analyzer through the span port.

vii) Adjust the span so that the analyzer reads 100 percent of low scale.

viii) Observe the voltmeter reading at 100 percent full scale of the analyzer and record the voltage value. Alternatively, adjust the chart recorder so that full scale is equivalent to the analyzer full scale.

ix) Zero and span the analyzer with the analytical gases to the proper values.

x) Fill a sample bag with span gas.

xi) Introduce the span gas from the sample bag to the analyzer through the probe.

xii) After the reading has stabilized, observe the voltmeter or chart recorder. Record the highest value and the lowest value over a 3 minute time span. The scale can be changed for better resolution.

xiii) Fill another sample bag with CO_2.

xiv) Introduce the CO_2 through the sample probe.

xv) Record the average voltmeter or chart recorder reading. The scale can be changed for better resolution.

xvi) Fill a sample bag (after purging with N_2) with NO_2.

xvii) Introduce the NO_2 through the sample probe.

xviii) Record the average voltmeter or chart recorder reading. The scale can be changed for better resolution.

xix) Start the steam generator.

xx) Attach the probe to the mixing chamber and adjust the dilution valve to obtain a 40°C (101°F) temperature in the dilution box. To prevent condensation in the analysis system this test should be performed with an ambient temperature between 30°C and 40°C. This test cannot be performed correctly when testing at the lower ambient temperature conditions specified in Section G of this chapter, and should therefore, be omitted when testing under Section G.

xxi) Sample from the dilution box.

xxii) Record the average voltmeter or chart recorder reading. The scale can be changed for better resolution.

xxiii) Reconnect the water trap.

xxiv) Repeat steps xix) through xxii) with an ambient temperature at the same value as in step xx) and 40°C in the dilution box. When repeating this test at the operating environmental conditions specified in Section G of this chapter, perform this test with a 40°C dilution box temperature and the analysis system at the prevailing ambient temperature.

c) Calculations

i) Compute the difference between the high and low reading recorded in step b) xii), then divide that result by the full scale voltage value recorded in step b) vii). This value, expressed as a percentage and divided by 2, is defined as noise of the analyzer.

ii) Divide the value recorded in step b) xv) by the full scale voltage value recorded in step b) vii). The result, expressed as a percentage, is the CO_2 interference of the analyzer.

iii) Divide the value recorded in step b)xviii) by the full scale voltage value recorded in step b)vii). The result, expressed as a percentage, is the NO_2 interference of the analyzer.

iv) Divide the value recorded in step b)xxii) by the full scale voltage value recorded in step b)vii). The result, expressed as a percentage, is the water interference of the analyzer.

v) Divide the value recorded in step b)xxiv) by the full scale voltage value recorded in step b)vii). The result, expressed as a percentage, is the water interference of the system.

d) Acceptance Criteria

i) If the percentages calculated in paragraph c) for the analyzer are equal to or less than the specifications for noise and gaseous interferences (Chapter V, Section E.), then the noise and gaseous interferences are acceptable.

Reference values: noise = ±0.5%

CO_2 = 1.5% fs L.S. HC; 1.0% fs L.S. CO
NO_2 = 1.5% fs L.S. HC; 1.0% fs L.S. CO
H_2O = 1.5% fs L.S. HC; 1.0% fs L.S. CO

ii) Inspect the analysis system between the water trap and the optical bench for condensed water. If water vapor droplets are found repeat the water checking test for a longer period of time. If substantial water is found, the effectiveness of the water trap is not acceptable.

9. Analyzer Electrical Interference Test Procedure

a) Equipment Required

i) Candidate instrument.

ii) One high impedence (1megohm or greater) digital volt meter with at least 4½ digit resolution. Generally, a 2 volt (1.9999 v) and a 20 volt (19.999 v) scale will be adequate. A chart recorder of similar impedence, resolution, and scaling may be used in place of a voltmeter.

iii) One vehicle with high energy ignition system, and solid core ignition and coil wires.

iv) One 3 amp or more variable speed (commutator type) hand drill with a plastic handle.

v) One 20 foot extension cord with 3 sixteen gauge wires, and a 2 plug outlet. For systems without ground fault circuits, a 2 wire extention cord or a non-grounded adaptor will be required.

vi) A CB transmitter at or near FCC legal maximum power with a matching antenna.

vii) One variable voltage transformer (90v to 130vAC).

viii) One span gas between 70 and 90 percent of full scale on the low range.

ix) One dry flannel cloth.

b) Test Sequence

i) Remove the analyzer's protective cover.

ii) Locate the meter readout, and attach the voltmeter or chart recorder leads to the meter terminals.

iii) Reinstall the analyzer's protective cover.

iv) Check the outlet box to be used for proper hot lead/ neutral lead orientation and for proper ground.

v) Plug the analyzer's power cord into a 2-outlet grounded electrical outlet box and warm up the analyzer.

vi) Reserved

vii) Reserved

viii) Introduce the span gas through the span port, and adjust the span so that the analyzer reads 100 percent of low scale. It is not necessary to substitute the electrical span in pressure and temperature compensated models for this gas span.

ix) Observe the voltmeter or chart recorder reading at 100 percent full scale of the analyzer, and record the voltage value.

x) Zero and span the analyzer with the analytical gases to the proper values. Record the values. It is not necessary to substitute the electrical span in compensated models for this gas span.

xi) Introduce span gas to the analyzer. Record the average span gas voltage levels over a 5 minute time span. The scale can be changed for better resolution.

xii) Either move the analyzer or the vehicle (engine compartment) to within 2 feet of each other.

xiii) Introduce the span gas to the analyzer.

xiv) Open the hood and start the vehicle.

xv) Record the average span gas voltage level during a 5 minute time span.

xvi) Stop the vehicle engine.

xvii) Plug the electric drill into the other outlet of the same receptacle that the analyzer is connected to.

xviii) Move the drill at approximately 3 to 4 feet high to within 12 inches of the analyzer. At four locations around the analyzer vary the drill speed from minimum to maximum speed. Attempt to locate the positions that provide the greatest interference.

xix) Record the average span gas voltage level at each position.

xx) Key the CB radio within 50 feet of the analyzer.

xxi) Record the average span gas voltage level when the CB radio is transmitting.

xxi) Turn the analyzer off.

xxiii) Plug the extension cord into the variable voltage transformer and set the transformer output to 110 volts.

xxiv) Turn the analyzer on, and warm it up.

xxv) Check the zero and span. If necessary reset to the exact voltage level recorded in step b) x). It is not necessary to substitute the electrical span in compensated models for this gas span.

xxvi) Repeat step b) xii) through xxi).

xxvii) Record the average span gas voltage level as indicated in steps b) xv), xix), and xxi).

xxviii) Reduce the transformer output voltage to 90 volts. Let analyzer stabilize for 2 minutes.

xxix) Repeat steps b) viii) through xxi) with the extention cord and 90 volt set-up. Non-relevant set-up steps may be omitted.

xxx) Increase the transformer output to 130 volts. Let the analyzer stabilize for 2 minutes.

xxxi) Repeat steps b) viii) through xxi) with the extension cord and 130 volt set-up. Non-relevant set-up steps may be omitted.

xxxii) If the unit has an analog meter, observe and record the meter reading with span gas.

xxxiii) Rub the meter face 10 times with the dry flannel cloth in the up-scale direction. Record the meter reading. (Only required at lowest and dryest temperature used during evaluation testing).

c) Calculations

i) Compute the difference between each set of voltage levels recorded in step b) x) and b) xv). The maximum difference expressed as a percentage of the voltage recorded in step b) ix) is defined as the RF interference (RFI).

ii) Compute the difference between each set of voltage levels recorded in step b) x) and b) xx). The maximum difference expressed as a percentage of the voltage recorded in step b)ix) is defined as the induction interference.

iii) Compute the difference between each set of voltage levels recorded in step b)x) and b)xxi). The maximum difference expressed as a percentage of the voltage recorded in step b)ix) is defined as the VHF interference.

iv) Compute the difference between the voltage levels recorded in step b) x) and step b) xxvii). The largest result expressed as a percentage of the voltage recorded in step b) ix) is defined as the line interference.

v) Compute the difference between the voltage levels recorded in step b) x) and b) xxix). Compute the difference between the voltage levels recorded in step b) x) and b) xxxi). The largest value of the results expressed as a percentage of the voltage recorded in step b) ix) is defined as the line voltage interference.

vi) Compute the difference between the meter reading recorded in step b) xxxii) and b) xxxiii). Also compute the difference as a percentage of full scale. The difference is defined as the static electricity interference.

d) Acceptance Criterion

i) If the percentages calculated in paragraph c) are equal to or less than the electronic interference specifications (Chapter VII, Section E.), then the electrical interferences are acceptable.

Reference values:	RFI	= 1.0% fs L.S.
	VHF	= 1.0% fs L.S.
	Induction	= 1.0% fs L.S.
	Line	= 1.0% fs L.S.
	Line Voltage	= 1.0% fs L.S.
	Static	= 1 meter division or 2½ fs L.S. whichever is greatest.

10. Propane to Hexane Conversion Factor Test Procedure

a) Testing Concepts

i) The conversion factor shall be evaluated at two hexane concentration levels.

1) 250 ppmh (± 15 ppmh) on the low scale, and

2) 1500 ppmh (± 150 ppmh) on the high scale.

ii) A minimum of three samples of the hexane gas at each concentration level shall be performed.

iii) Because of the exceptional hang-up characteristics of hexane, an auxilliary sample/spanning system that is specially constructed to be essentially hang-up free may be used. The auxilliary system should be of laboratory quality, and may bypass the candidate analysis system controls.

iv) The test should always be conducted at an ambient temperature greater than 20°C (68°F).

v) A flame ionization detector (FID) properly optimized and calibrated (see 40 CFR 86 Subpart D or N) may be used to provide additional quality control on the conversion factor determination procedure.

b) Test Sequence

i) Set up the test equipment.

ii) Warm-up the candidate analyzer.

iii) Leak check the system used.

iv) Span the analyzer on the low range with a propane calibration gas near (± 5%) the expected low concentration hexane response, and with bottled zero gas. Use the propane to hexane conversion factor indicated on the analyzer.

v) Alternately cycle low concentration hexane gas and the calibration gas through the analyzer a total of 3 or more times.

vi) Record each response for each gas.

vii) Span the analyzer on the high range with a propane calibration gas near (± 5%) the expected high concentration response, and bottled zero gas. Use the propane to hexane conversion factor indicated on the analyzer.

viii) Alternately cycle the high concentration hexane gas and the calibration gas through the analyzer a total of three or more times.

ix) Record each response for each gas.

c) Calculations

i) For the values recorded in step b) vi), and b) ix), compute the mean ($\bar{x}$) and standard deviation(s) for the hexane response and the propane response.

ii) Use an of 0.05 and the student's "t" test to determine the confidence interval of the population mean at the 90% confidence level based on the values computed in step c) i) for each range.

iii) Use the following equation to determine the mean propane to hexane conversion factor (CF) for each range:

$$CF = \frac{(.5) + (.5)(\bar{x}_{hex} - \text{Hex Cal})}{\text{Hex Cal}}$$

where:

$\bar{x}$ hex = the mean hexane response determined in step c) i).

Hex Cal = concentration of hexane calibration gas.

iv) Determine if sufficient number of cycles (steps b) v) and b) viii)) were run on each range by the following equation:

$$0.01 \leq \frac{(.5)(\bar{x}_{hex} - x_{CI}) \pm (.5)\ \text{Hex Cal}}{\text{Hex Cal}}$$

where:

$\bar{x}$ hex = the mean hexane response determined in step c) i).

x_{CI} = the confidence interval determined in step c) ii).

Hex Cal = concentration of hexane calibration gas.

v) For each range, multiply the mean propane response ($\bar{x}$) determined in step c) i) by the CF computed in step c) iii).

vi) Determine the difference between the CFs for each range, and determine the mean CF.

d) Acceptance Criteria

i) If the value computed in step c) iv) is greater than 0.01, perform additional cycles (see steps b) v) and b) viii)) until the computed value is less than 0.01.

ii) If the difference between the CFs computed for each range (step c) vi)) is greater than .030 a sperate CF must be used for each range. If the difference is less than .030, a mean CF may be used for both ranges.

iii) The CF value(s) determined by step d) iii) must agree exactly with the CF posted on the analyzer. ASTM round-off shall be used.

iv) The mean propane value determined in step c) v) must agree with the propane calibration gas within 1 percent of the propane calibration gas concentration.

v) The final CF value must be between the limits identified in Chapter VII, Section E, paragraph 9.
(Reference value: $0.48 \leq CF \leq .56$)

F. Sample System Test Procedures

1. Sample Cell Pressure Variation, Low Flow, and Response Time

a) Test Equipment

i) Candidate instrument system.

ii) One span gas cylinder with a concentration between 70 and 90 percent of full scale, and bottled zero gas.

iii) One gauge (0-30 inches of water).

iv) One pinch clamp.

v) One Tedlar sample bag (approximately 3 cubic foot capacity).

vi) One 3-way ball valve, minimum orifice size is .180 inches.

vii) One stop watch or timer.

ix) Associated fittings and lines (non-reactive material).

b) Testing Sequence

This test procedure is written around parallel HC and CO analyzers, and should be performed on each analyzer. If the analyzers are in a series configuration then an additional pressure gauge will be required, but the test can be performed on both analyzers at the same time. A special test set-up that attaches to the probe and provides gas at approximately the same pressure as occurs during sampling may be substituted for the Tedlar bag, ball valve, and timer. Using a solenoid valve interfaced with a timer or chart recorder will provide more accurate results.

i) Identify the sample line entering the sample cell.

ii) Install a tee fitting in the sample line immediately upstream of the sample cell (in as close as practical). Install the tee with the branch pointing up.

iii) Connect the gauge to the tee with the suitable length of flexible tubing.

iv) Warm up the analyzer.

v) Zero the analyzer.

vi) Introduce span gas through the spanning network. Record the pressure gauge reading, and the span response.

vii) Recheck the zero. If the zero has shifted repeat steps v), vi), and vii).

viii) Switch the analyzer from span gas flow to sample flow (pump on).

ix) Record the maximum and minimum fluctuations in the gauge reading.

x) Attach the pinch clamp to the pressure gauge line. Slowly pinch the line until the gauge fluctuations are minimized.

xi) The gauge reading should be approximately halfway between the readings recorded in step ix). Record the stabilized gauge reading in step x).

xii) Attach the common port of the 3-way valve to the probe with a leak free adapter.

xiii) Attach a short length of tube to one of the remaining two ports of the three-way valve, and sample room air through the tube.

xiv) Fill the sample bag with span gas.

xv) Attach the sample bag to the remaining port of the 3-way valve.

xvi) The 3-way valve should be sampling room air.

xvii) switch the 3-way valve to the sample bag, compare the stabilized concentration reading of the bag to the reading in step vi). A difference of more than 1 percent from the concentration reading in step vi) could indicate a leak in the system. Repair any leaks, and restart the procedure at step b)i).

xviii) Recheck the zero by switching the 3 way valve back to room air.

xix) Identify the concentration value corresponding to 95% of the span gas in the bag. Record the 95% value.

xx) Switch the 3-way valve to the sample bag and simultaneously start a timer.

xxi) When the analyzer response reaches the 95% value stop the timer. Record the elapsed time.

xxii) Record the sample cell pressure after the analyzer reading has stabilized. Record the stabilized analyzer concentration reading.

xxiii) Identify the concentration value (5%) corresponding to the stabilized reading in step xxii) (100%) minus the 95% value identified in step xix).

xxiv) switch the 3-way value back to room air and simultaneously start the timer.

xxv) When the analyzer reaches the 5% value, stop the timer. Record the elapsed time.

xxvi) Connect the needle valve between the probe and the 3-way valve.

xxvii) Adjust the needle valve until the low flow indicator is just barely activated.

xxviii) Repeat steps xvi) through xxv).

xxix) Use the same 95% and 5% values identified in step xix) and xxiii).

xxx) Record the 5% and 95% response times.

xxxi) Record the stabilized concentration reading, and sample cell pressure in the same manner used in step xxii).

c) Calculations

i) Compute the difference in pressure between step vi) and step xi), and step vi) and step xxii). The values will be the pressure difference between spanning and sampling.

ii) Compute the difference between maximum and minimum pressure readings in step b) ix). The value will be the pressure variation during sampling.

iii) Compute the difference in pressure between step xi) and step b) xxxi). The value is the difference in pressure variation between normal flow and low flow conditions.

iv) Compute the percentage change in analyzer gas response between step b) xxii) and step b) xxxi).

d) Acceptance Criteria

i) If the calculated value in steps c)i, and c)iii are less than 4 inches of water, and less then 6 inches of water for step c)ii, the pressure variations in the analyzer flow system under these test conditions are acceptable.

ii) If the change in analyzer response computed in step c)iv is less than 1.5 percent and the elapsed times recorded in step b) xxx) are less than 14 seconds, the low flow indicator system is acceptable as well as the system response time.

iii) If the elapsed time in steps b) xxi) and b) xxv) is less then 14 seconds, the system response time is acceptable under normal conditions.

iv) It is recommended that the sample cell pressure gauge(s) remain hooked up for the duration of the analyzer check out. If the sample pressure varies by more then 4 inches of water from the most recent span pressure, then the acceptance in d)i is void.

2. Maximum Sample Cell Pressure Variation during Sampling Test Procedure

   (See Test Procedure F.1)

3. Maximum Sample Cell Pressure Variation Between Normal Flow and Low Flow Indication Test Procedure

   (See Test Procedure F.1)

4. Response Time Test Procedure

   (See Test Procedure F.1)

5. System Leakage Test Procedures

a) Equipment Required

i) Candidate instrument.

ii) One tee fitting.

iii) One needle valve.

iv) One span gas 70 to 90 percent of full scale on the low range, and bottled zero gas.

v) Associate lines and fittings (non-reactive).

b) Test Sequence

This sequence is written to evaluate the ease of operation of the leak checking equipment. It may also be used to correlate abbreviated leak checks with the gas comparison test.

i) Install the tee fitting between the probe and the sample line.

ii) Attach the needle valve to the remaining port of the tee and close the valve.

iii) Warm up the analyzer.

iv) Zero and span the analyzer with the analytical gases. It is not necessary to substitute the electrical span in compensated models for this gas span.

v) Record the span value.

vi) Place the probe in the leak check receptacle.

vii) Record the analyzer response to span gas introduced through the leak check recepticle, probe, and sample line.

viii) If the analyzer response in step vii) differs from the response in step v) by more than 1 percent of the value recorded in step v), check the system for leaks or other problems. Restart the procedure at step iii).

ix) Compute the concentration value that would result from a leak of 3 percent.

x) Gradually open the needle valve until the computed concentration valve is obtained.

xi) Use the bubble check method to check for leaks in the spanning system.

xii) If the unit is equipped with an abbreviated leak check or leak warning light, perform the manufacturers leak check with the calibrated leak from step x).

xiii) Repeat steps ix) through xi) with leaks of 1%, 2%, and 4%, if the unit is equipped with an abbreviated leak check.

c) Calculations

i) Plot the leak rate against the manufacturers abbreviated leak check criteria (linear regression is acceptable).

d) Acceptance Criteria

i) If the spanning system shows significant leaks at fittings, attempt to repair the leaks by tightening or replacing the fittings. If leaks occur in other locations of the spanning system, or appear to be the result of system design, an engineering report must be submitted by the analyzer manufacturer describing the causes and preventive remedies for the leak prior final acceptance of the system.

ii) The relation of leak rate to the abbreviated checking criteria must be single valued, and of sufficient magnitude that interpolation of the exact leak rate can be made with little difficulty.

6. HC Hang-up Test Procedure
(See Test Procedure C.4.)

G. Operating Environmental Test Procedure

1. Test Procedure

a) Equipment required

i) Candidate instrument

ii) Environmental chamber with temperature capability between 35°F and 110°F, and humidity capability between 10 and 99 percent relative humidity.

b) Test Conditions

i) 105°F (± 5°F) with a relative humidity between 80 and 85 percent (non-condensing).

ii) 40°F (± 5°F) with a relative humidity between 75 and 80 percent with a 10 mph wind.

iii) 35°F (± 5°F) with a relative humidity between 10 and 20 percent.

c) Required Tests of each test condition (Test Procedure numbers are given in parentheses).

i) System Warm-up (H.1.a))

ii) System Leakage (F.5.)

iii) Sample Line Crush Test (C.2.)

iv) Analyzer Calibration Curve (E.1.)

v) Pressure and Temperature Compensation (E.3. b) and c))

vi) Analyzer Zero and Span Drift (E.4.)

vii) Sample Cell Temperature (as applicable, see E.7. and H.1.)

viii) Analyzer Water Interference (E.8.)

ix) Sample Cell Pressure Variation, Low Flow, and Response Time (F.1.)

x) HC hang-up (C.4)

xi) If used, all automatic systems (Chapter VIII)

xii) If used, anti-dilution system

xiii) If used, loaded mode kit

xiv) If used, automatic data collection system

d) Test Sequence

i) The analyzer shall be turned off and allowed to stabilize at least 3 hours at the test condition prior to beginning the performance check.

ii) The warm-up test followed by the leak check test shall be the first two tests performed at each test condition.

iii) The remaining tests may be performed in any convenient order.

iv) An additional leak check shall be performed at the completion of the required tests for each test condition.

v) The first test condition shall be the 35°F condition followed by the 40°F and the 105°F conditions.

e) Acceptance Criteria

i) If the analysis system passes all of the individual test requirements as specified by each test in c) and d), then the environmental operating characteristics of the system are acceptable.

H. Fail-Safe System(s)

1. Warm-up Lock-out Test Procedure

a) Equipment Required

i) Candidate analyzer.

ii) The equipment required to perform the Analyzer Sample Cell Temperature Test Procedure (see Section E.7.), if the unit uses a heated sample cell (not required on other units).

iii) The equipment required to Perform the Analyzer Zero Test Procedure (see Section E.4.).

iv) A timer.

b) Test Sequence

i) Follow the basic measurement preparations indicated in Test Procedures E.4. and E.7.

ii) After the analyzer has stabilized at the ambient conditions as determined by Test Procedure E.7. Turn on the analyzer power and simultaneously start a timer. (A chart recorder may be used).

iii) The chart recorder must indicate both negative and positive zero drift. If necessary, offset the chart recorder zero 5 units up scale.

iv) As soon as the warm-up lock-out feature deactivates, record the elapsed time from power on, the sample cell temperature, and immediately zero and span the analyzer with analytical gases per manufacturer's operating instructions. Simultaneously, start the chart recorder (in already started, mark the chart) at a minimum chart speed of 0.5 inches per minute.

v) Immediately after spanning, begin sampling ambient air (or analytical zero gas at the ambient temperature) through the sample line.

vi) Monitor the zero drift and the sample cell temperature for 5 minutes.

vii) Record the lowest sample cell temperature during the 5 minute period.

c) Calculations

i) Locate on the chart the maximum and minimum analyzer zero-response during the 5 minute period.

ii) Compute the difference (as a percentage of full scale chart deflection) between the analyzer zero-response determined by the span check in step b) iv) and the maximum zero-response, and then the minimum zero-response as identified in step c) i).

iii) Determine the largest difference in step c) ii) and multiply it by 2 —— (zero drift).

d) Acceptance Criteria

i) If the temperature observed in step ii) 2) is approximately the same as the ambient temperature, the analyzer is properly stabilized.

ii) If the temperatures recorded in step ii) 4) and step ii) 7) are equal to or greater than the specifications for sample cell temperature, the sample cell temperature is acceptable. (Reference value: 49°C (120.2°F)).

iii) While monitoring the sample cell temperature during the analyzer check-out procedure, if the temperature is less than the specifications when concentration data (span or sample) is read, the acceptance in step ii) is void.

iv) If the zero drift, as calculated in step c) iii) is less than the specifications for zero drift (Chapter VII, Section E.), then the zero drift after warm up is acceptable. (Reference value: ±2% fs L.S.).

v) Acceptance of the above criteria constitutes acceptance of the Warm-up Lock-out system.

vi) If the analyzer manufacturer indicates a typical lock-out elapsed time to the ultimate user, then the manufacturer must show that the elapsed time supplied to the user is truly typical if the time recorded in step b) iv) is more than 30 percent longer than the time indicated to the user. The time recorded in step b) iv) must be reported in the evaluation report for each environmental condition.

2. Analyzer Low Flow Test Procedure

i) See Test Procedure F.1., Sample Cell Pressure Variation, Low Flow, and Response Time.

ii) Visual Observation of Features

I. System Correlation Test Procedures

The correlation procedure is designed to evaluate the performance of the I/M analyzers when sampling auto exhaust. The NDIR procedure is slightly different from the FID HC correlation procedure. However, it is expected the data collection phase of each procedure can occur simultaneously. For clarity they will be presented as separate procedures. Note: the FID procedure is not required for accreditation.

1. NDIR Analyzer Correlation Test Procedure

a) Equipment Required

i) Candidate instrument.

ii) A raw exhaust CO analysis system meeting the requirements of 40CFR 86, Subpart D, for gasoline-fueled engines.

iii) A laboratory grade NDIR HC analyzer substantially similar in quality to the laboratory CO analyzer, and operated according to the requirements for general NDIR analysis of gasoline-fueled engines contained in 40 CFR 86, Subpart D.

iv) A tailpipe extension that meets the probe location requirements in 40CFR 86 Section 312-79 (c) (v).

v) Two test vehicles.

vi) Calibration gases for each range used on both the candidate analyzers and the reference analyzer. In this test procedure, calibration gases will be used instead of span gases to span both analysis systems. The calibration gases should be between 70 and 90 percent of full scale on each range used. Calibration gases for the Subpart D analysis system shall meet or exceed the requirements specified in Subpart D.

vii) Option: An adjustable dilution box and mixing chamber may be used to obtain different exhaust concentration levels from the vehicle. The dilution box and mixing chamber would be installed between the tailpipe and the analysis system probes.

viii) Option: A chassis dynamometer would be useful for loading the vehicle to obtain different emission levels, but is not required.

b) Test vehicles

i) One 1975 or later non-catalyst light-duty vehicle (LDV), LDT, or HDG is acceptable.

ii) One 1978 or later oxidation catalyst equipped vehicle with air injection.

iii) All vehicles must be in good operating condition with all emission control systems functional. A 1975 FTP type test may be performed on the vehicle to verify functional operation of the emission controls.

iv) Fuel use shall meet the most recent EPA MVEL specifications for certification test fuel.

c) Test Procedure Overview

The correlation procedure consists of testing the candidate analyzer at several points on each range. The range scale of the candidate analyzer determines the approximate test points. The exact test points are then determined by the concentration levels observed by the reference system. The exact test points are then replicated several times (minimum of 6) based on the reference system response values. This replicate data is then analyzed to determine correlation between the candidate system and the reference system.

d) Test Sequence

i) Select a test vehicle, and warm up that vehicle with at least 30 minutes of hard load. (freeway operation, hard accelerations, etc.

ii) Prepare the analysis systems for measurement (i.e. warm-up, spanning etc.) operate the reference system according to the provisions in Subpart D where applicable.

iii) Insert the probe of the candidate instrument into the tailpipe approximately 16 inches.

iv) Operate the vehicle (or adjust the dilution box) to obtain stable concentration readings at approximately 20, 50, 70 and 90 percent of full scale concentration value on the low range of the candidate analyzer.

v) Select the lowest useable range on the Subpart D system for each test point in d)iv) (see § 86.338).

vi) Sample for approximately 1 minute at each test point.

vii) Record the average emission value of the candidate instrument and the average chart deflection from the reference system over the last 10 seconds for each test point. The two readings recorded at each test point should be recorded over the same time frame, and are defined as a "paired" data point.

viii) Select the high range of the candidate instrument.

ix) Operate the vehicle (or adjust the dilution box) to obtain stable readings at approximately 20, 50, 70, and 90 percent of full scale on the high range of the candidate instrument. If the higher emission values require impractical vehicle operation, cease data generation and continue with the test procedure. At least one vehicle should be able to achieve the higher values.

x) For the attainable test points in the preceding step, repeat step d)vii).

xi) The chart deflections recorded in steps d)vii) and d)x) for the Subpart D system are now defined as "reference set points" that will be used for the remainder of the correlation test. When repeating the test sequence with the same vehicle or a different vehicle, the vehicle or dilution box should be adjusted to obtain, as close as possible, the exact "reference" chart deflection. For the test points not attainable in step d)ix), the chart deflection of the reference system becomes the set point the first time a data pair is recorded for that test point.

xii) Repeat steps d) iv) through d) x) at the set points described in step d)xi). Record the emission values from the candidate system, and the chart deflections from the reference system.

xiii) Ground or short two plug wires on V8 engines (opposite sides of intake manifold), or one plug wire for 6 cylinder and 4 cylinder engines.

xiv) Perform steps d)iv) through d)x) at the set points described in step d)xi) a minimum of three times. Record the emission values from the candidate system, and the chart deflections from the reference system.

xv) Select the 2nd test vehicle, and repeat steps d)iv) through d)xiv) at the set points described in step d)xi). Record the emission values from the candidate system, and the chart deflections from the reference system.

xvi) Repeat the procedure as necessary to obtain a minimum of 6 replicate responses at each test point.

e) Calculations

i) For the candidate system compute the mean ($\bar{x}$) and standard deviation(s) of the emission values for each test point.

ii) For the reference system convert each chart deflection to a concentration value from the analyzer calibration curve.

iii) For the reference system compute the mean ($\bar{x}$) and standard deviation(s) concentration values for each test point.

iv) Compute the normalized precision difference ($_{\Delta}$ P) for each test point by:

$$\Delta P = ((Ks/\bar{x}) \text{ candidate}) - ((Ks/\bar{x}) \text{ reference})$$

where:

Sample Size	K	Sample Size	K
5	3.5	10	2.5
6	3.1	11	2.46
7	2.9	12	2.40
8	2.7	13	2.36
9	2.6	14	2.31

v) For each range of the candidate analyzer perform a linear regression on all of the paired data that were measured on that range. Force the regression through zero. The reference system is the independent variable. Identify the slope(m) of the regression line.

vi) For each range of the candidate analyzer compute the ratio(R) of the analyzer mean concentrations for each test point corrected for the slope(m) identified in the preceding step by:

$$R = (\bar{x} \text{ reference}/\bar{x} \text{ candidate})m$$

f) Acceptance Criteria

i) Identify the largest Δ P value. If the largest Δ P value is less than or equal to the specification for P, then the in-use precision of the candidate system is acceptable.
(Reference value: $\Delta P \leq 5\%$).

ii) If the slope(m) for each range of the candidate analyzer is within the limits for slope, then the slope test results are acceptable.
(Reference value: $0.95 \leq R \leq 1.10$)

iii) Identify the minimum and the maximum ratio(R) of slope corrected mean concentration values. If the minimum and maximum ratios are within the range specified, then the mean concentration ratio test results are acceptable.
(Reference value: $0.90 \leq R \leq 1.10$)

2. FID Analyzer Correlation Test Procedure (Not required for accreditation)

a) Equipment required

i) Candidate instrument.

ii) An HC analysis system meeting the requirements of 40CFR86, Subpart D for gasoline-fueled engines.

iii) A tailpipe extension that meets the probe location requirements in 40CFR86 Section 312(c)(v).

iv) Three test vehicles.

v) Calibration gases for each range used by both the candidate analyzers and the reference analyzer. In this test procedure, calibration gases will be used instead of span gases to span both analysis systems. The gases should be between 60 and 90 percent of full scale on each range used.

vi) Calibration gases for the Subpart D analysis system shall meet or exceed the requirements specified in Subpart D.

vii) Option: A dilution system that allows the auto exhaust to be diluted in a controlled manner with a suitable mixing chamber, may be used to obtain different exhaust concentration levels from the vehicle.

viii) Option: A chassis dynamometer may be used with or without the dilution system to obtain different concentration levels.

b) Test Vehicles

i) The type of test vehicle required for the FID correlation test are the same as the type required for the NDIR correlation. Generally it is preferred that the same vehicles be used for both correlations.

c) Test Procedure Overview

The correlation procedure consists of testing the candidate analyzer at several points on each range. The range scale of the candidate analyzer determines the approximate test points. The exact test points are then determined by the concentration levels observed by the reference system. The exact test points are then replicated several times (minimum of 6) based on the reference system response values. This replicate data is then analyzed to determine correlation between the candidate system and the reference system.

d) Test Sequence

The test sequence is identical to CO correlation test required with the following exception.

i) Stabilized concentration readings of approximately 10, 20, 35, 50, 70, and 90 percent of full scale concentration values should be substituted for the value in step 1.d)iv) and 1.d)ix). Record the HC concentration value from the candidate analyzer as ppmh or ppmC6.

e) Calculations

i) For the candidate system compute the mean ($\bar{x}$) and standard deviation(s) of the emission values for each test point.

ii) For the reference system convert each chart deflection to a concentration value in ppm C3 (propane) from the analyzer calibration curve.

iii) For the reference system compute the mean ($\bar{x}$) and standard deviation(s) concentration values for each test point.

iv) Compute the normalized precision difference (Δ P) for each test point by:

$$\Delta P = ((Ks/\bar{x}) \text{ candidate}) - ((Ks/\bar{x}) \text{ reference FID})$$

where:

Sample Size	K	Sample Size	K
5	3.5	10	2.5
6	3.1	11	2.46
7	2.9	12	2.40
8	2.7	13	2.36
9	2.6	14	2.31

v) For each range of the candidate analyzer perofrm a linear regression on all of the paired data that were measured on that range. Force the regression through zero. The reference system is the independent variable. Identify the slope(m) of the regression line.

vi) For each range of the candidate analyzer compute the ratio(R) of the analyzer mean concentrations for each test point corrected for the slope(m) identified in the preceeding step by:

$$R = (\bar{x} \text{ reference FID}/\bar{x} \text{ candidate})m$$

f) Acceptance Criteria

i) For HC analyzers the following FID comparison should be available:

1) Precision
2) Slope Comparison
3) Ratio of Modal Averages

J. Micro Processor Systems

In general, the evaluation of microprocessor systems will consist of operating each of the automatic features to insure that: a) each feature provides equivalent results as would be obtained by a manual system, and b) each feature has the necessary controls to perform the required actions conveniently and easily. Further guidance follows.

1. Automatic Zero/Span Check Test Procedure

a) The gas spanning feature must be used throughout the entire evaluation procedure unless noted otherwise (e.g. pressure and temperature compensation, Section E.3. b)).

b) The automatic span system shall be used with calibration gas (instead of span gas) for the Calibration Curve Test Procedure (E.1.).

c) Self-explanatory Test Procedures for the other requirements.

2. Automatic Leak-Check

a) If the system is equipped with an automatic leak-check feature, utilize test procedure F.5. with the following changes.

i) In step b) x) of F.5. gradually open the needle valve until the leak check fail light just comes on. Record the observed concentration value.

ii) Then compare the calculated 3% leak concentration (step b) ix) of F.5.) to the concentration value observed in a) i) of this section.

b) Repeat the test three times.

c) Compute the standard deviation and mean of the observed concentration (step a) i)).

d) The mean minus one standard deviation should be greater than the calculated 3% leak concentration.

e) Check the interlock requirements.

3. Automatic Hang-up Check

a) Utilize test procedure F.6. to evaluate the automatic hang-up feature.

b) Check the interlock requirements.

4. Automatic Read Feature

i) The automatic read feature shall be deactivated for all evaluation testing except:

1) The response time portion of test procedure F.1. shall be rerun with the automatic read feature operational.

2) All system correlation tests (Procedures in Section I) shall be run with the automatic read feature operational.

3) Other tests self explanatory.

5. Dual Tailpipe

a) When evaluating the dual tailpipe feature, the difference between the concentrations to be averaged shall be:

i) case 1: HC $\geq$ 200 ppmh
CO $\geq$ 1%

ii) case 2: 10 ppmh $\leq$ HC $\leq$ 20 ppmh
.1% $\leq$ CO $\leq$ .2%

b) A single tailpipe at the different concentrations may be used.

6. Automatic Test Sequence

a) Evaluate the automatic test sequence for proper function with both single and dual tailpipe vehicles over both the pre-81 and post-81 test procedures.

b) Utilize both the same and different cutpoints for the two mode tests when evaluating the automatic test sequence feature.

7. Printer Feature

If the analysis system is equipped with a printer, the printer shall be checked for proper operation. The printer shall provide the official system results to be used in the correlation procedures (Section I).

8. Vehicle Diagnosis Feature

Check for proper operation. No other test procedures are required.

9. Anti-Tampering Feature

i) Visual observation